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AUGUST/SEPTEMBER 2006 VOL. 21 NO. 3

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FEATURES

DEPARTMENTS

Cover:
Always ready for a fight, an F-14A from the VF-154 "Black Knights" squadron, flying from the USS *Independence*, leaps at the lens of air-to-air master Katsuhiko Tokunaga.

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While other Smithsonian museums now mostly hire contractors for design services, we still maintain an in-house design staff. This enables us to keep the costs of our exhibits down—a real advantage, since the money to build them must come from patrons and donors. Our staff designers also have a thorough understanding of our museum: its structure and layout, our subject matter and collections, and the special challenges we face. Many of the objects we display, for example, are huge and heavy aircraft and spacecraft, and we accommodate millions of visitors wanting to see them.

The division comprises several designers with expertise in graphics, structural design, and lighting, along with project managers, a writer-editor, and an administrative assistant. Their work on an exhibition is a complex undertaking that requires much more than simply choosing pleasant colors and attractive displays. Everything is meticulously worked out, from the overall floor plan, to major and minor structural components, to the look and location of every exhibit element, to the size and style of the type used on labels. The division also manages the budget and schedule and coordinates the efforts of the entire project team.

Designers must realize their artistic vision within the confines of stringent accessibility codes. People in wheelchairs or with other physical limitations must be able to comfortably navigate the exhibition and enjoy as many of its features as possible. Type must be of a certain minimum size, contrast well with its background, and be displayed within a certain range of heights so it can be easily read. Lighting must be bright enough to illuminate pathways and objects, but not so intense that it damages light-sensitive artifacts. The health and security of the objects on display are of paramount concern.

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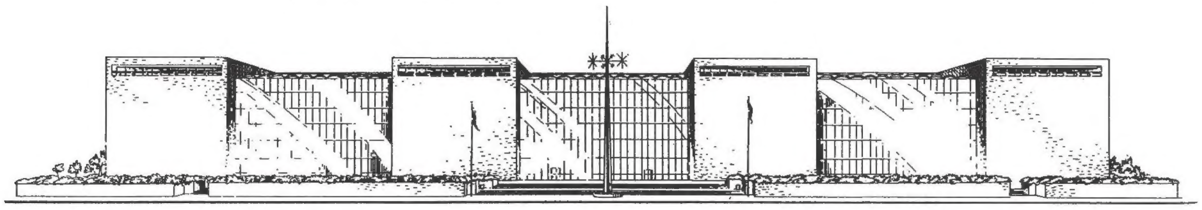
You, as a visitor, will hardly be aware of most of this. You may not notice the color palette, the type style, or the durability of the carpet. But you can be sure these things and more have been carefully developed and refined—it's all by design.

J.R. DAILEY IS THE DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM.



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Long Live the Climb King

I flew a very small part of the F4D program ("Beautiful Climber," June/July 2006) and also had an F4D destroyed beneath me. As I engaged the automatic flight control at 500 knots over Long Beach Harbor, I hit my head on the top of the canopy and received a negative-7-G hardover—same results as described by Robert Rahn. Wings bent down, fuselage broken, engine broken loose. I was surprised and pleased that it took me back to LAX [Los Angeles International Airport], where it was scrapped.

Another pilot had his blow up, literally, over Santa Monica Harbor at about the same speed. Pilot was just cruising along, there was a moment of confusion, and he was floating down in his parachute. Lucky for him he fell near a small boat that took him aboard and on to shore. Then he went promptly to the emergency room.

It was a really difficult airplane to get supersonic, although advertised as such, but what a climber! Never forget my first takeoff from LAX. Light the burner and around two minutes later I was at 40,000!

Drury Wood
via e-mail

Editors' note: Mr. Wood is the author of "50 Feet, 600 Knots" (Above & Beyond, Apr./May 2006).

The sidebar "See the Skyray" neglected to mention the XF4D displayed in front of the Naval Museum of Armament and Technology at Naval Air Weapons Station, China Lake, California.

Leo Budd
via e-mail

About 50 years ago, I spotted an F4D on an Air Force billboard. The headline said "FLY AIR FORCE." I wrote a story about it for my paper, *The Shreveport Times*, and we ran it with a picture of two Navy recruiters pointing at it.

We sent our story to the New Orleans bureau of the Associated Press, and after some rewriting the AP sent it over their national wires. The Air Force wasn't pleased and vigorously denied the plane was a Navy Skyray.

To counter the Air Force's denial, we ran pictures of the billboard and an F4D side by side. The Air Force insisted the latter was an artist's composite and not a picture of an F4D. I wish I could find those clippings.

Allan M. Lazarus
Shreveport, Louisiana

It Just Sounds Russian

"Boeing's Team Moscow" (Soundings, June/July 2006) refers to "Katiya design software." The software is CATIA, developed by Dassault Systems and marketed by IBM. It is an industry standard used by most engineering firms, especially aerospace ones. You can find out more at *www.catia.com*.

Jim Burch
Aerodyne Inc.
Madison, Alabama

Medical Helicopters: A Pilot's Opinion

As an emergency medical service helicopter pilot, I feel compelled to respond to "Thank You for Not Flying" (Commentary, June/July 2006).

Dr. Bledsoe says that in 2004 and 2005, 35 medical helicopter accidents occurred in the United States. According to my research into the records of the National Transportation Safety Board, in 2004 and 2005, there were 22 medical helicopter accidents (of which 10 were fatal, three with only a pilot aboard).

Bledsoe states that "[m]any companies opted for less-expensive, pre-owned, single-engine aircraft." So what? Those aircraft usually have undergone complete refurbishment and are well maintained. The crashes that have happened due to mechanical reasons (three of the 22 in 2004 and 2005) have not been in aircraft that

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Brian Grote is a flight instructor with 20 years aviation experience. He also writes monthly columns on subjects pertaining to aviation.

FLYBY

ARTICLE WRITTEN BY: BRIAN GROTE

Dear Brian,

I've been flying for over 20 years. My usual run is a Denver departure at 9pm, fly to Billings, on to Cheyenne and then back to Denver by 5am. I fly a King Air 350. I love my career and I pride myself on doing the best job I possibly can.

Last time out, however, I was making lots of little mistakes. I was cleared for the ILS Runway 35R into Denver, but I couldn't pick up ATIS. That's when I looked at my radios and noticed I had dialed in the wrong frequency. I glanced again and dialed in the right frequency. I continued though my checklist and set my Radar Altimeter to 5500 feet. I was ready to make my descent and start my approach. After the outer marker I glanced at my DH again and noticed that I had set my Radar Altimeter, 67 feet low. Luckily, I landed safely, bouncing the wheels just a little.

After a couple more days in the sky I could tell my eyesight was beginning to deteriorate. I knew I wouldn't be able to renew my first class medical if I didn't do anything about it. I was really worried and started asking my peers if there was anything I could do. A co-worker gave me a bottle of Claroxan™ and told me it would help me maintain my depth perception. I was skeptical at first, but tried it anyway. As it turns out, the stuff works great. The problem is, I ran out and don't know where to find more. Have you heard of this Claroxan™ stuff? Is it available in the States?

Jason, 46 – Seattle, WA

Jason,

Not only do I know of Claroxan™, it just so happens I take it everyday. Being a pilot myself, I know that perfect visual acuity is an asset none of us can afford to lose. That's why every pilot should be protecting their eyesight before it's too late.

Claroxan™ contains ingredients proven beneficial for the eyes. Among these ingredients are lutein and zeaxanthin – powerful antioxidants that have been clinically proven to protect the retina and macula and, in some cases, reverse the damaging effects of macular degeneration. These antioxidants block damaging UV rays and halt damaging free radical oxidation in the back of the eyes. They have also been clinically proven to decrease the risk of cataracts.

Claroxan™ also contains bilberry, an anti-oxidant known to improve night vision. Bilberry's night vision enhancing effects were first noticed in England in the early 1940's. The RAF ordered English fighter pilots to eat bilberry jam on toast figuring it would give them an advantage during night raid missions against the German Luftwaffe fighters.

Claroxan's unique proprietary formulation is completely safe, all-natural and extremely affordable. As far as ordering it, you can call them toll-free at 866.775.3937, or go to "www.claroxan.com/AAS". I usually get mine within a week after ordering.

Hope this helps!
Brian

THE himalayan CATARACT project

The Himalayan Cataract Project strives to eradicate preventable and curable blindness in the Himalaya through high-quality ophthalmic care, education, and establishment of a sustainable eye care infrastructure.

Based in Asia, at Kathmandu in Nepal, the Project is empowering local physicians to alleviate the suffering caused by blindness through unique programs including skills-transfer education, cost-recovery, research, and the creation of a world-class network of eye care facilities.

In 2004 and 2005, 3% of PacificHealth profits were donated to HCP for development and construction of eye facilities in the Himalaya.

Visit CureBlindness.org to learn more about HCP.

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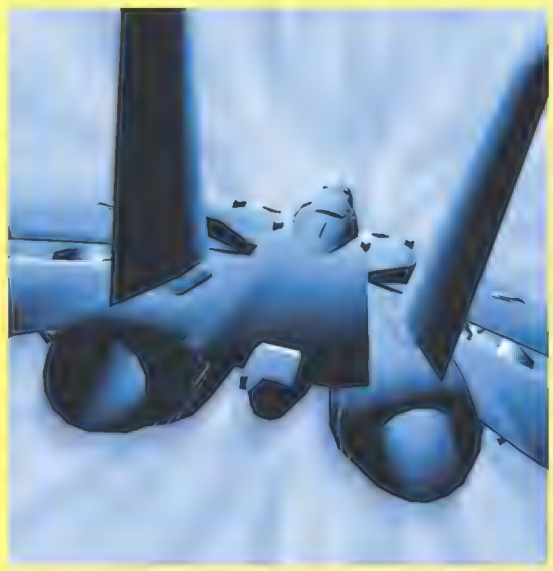
Sunlight, aging, and diet each cause damage to the retina and macula, which can lead to a decline in vision that glasses or contacts can't help. If you've experienced an increase in blurriness or difficulty seeing details at any range, then you know how valuable sharp vision can be. What you might not know is that in the past three years, a flood of new scientific research has been done on natural vision enhancement. This medical research suggests that ingredients in Claroxan™ may help maintain and even improve your vision, while at the same time giving you added protection against many ocular diseases

Claroxan™ may improve macular pigment density, which research shows has amazing effects on vision. By improving macular pigment density, ingredients in Claroxan™ may improve normal visual acuity, contrast sensitivity, and even glare reduction. Participants in one clinical study reported that ingredients in Claroxan™ improved their long range vision outdoors – in some cases, they were able to distinguish far away ridges up to 27 miles further than normal! Even if you have perfect vision now, Claroxan™ may help give you an edge by improving your visual reflexes and may allow you to pick up on moving objects faster than ever before.

People who count on their vision – people like pilots, hunters, military, and even pro athletes – trust Claroxan™ as the best source available for vision enhancement and protection. Claroxan™ is safe, effective, and extremely affordable. However, people with serious health concerns should consult a doctor before use.



LETTERS

have "already put in decades of work," but newer ones. The age of the aircraft involved in accidents has not been a factor.

Bledsoe also states that the "rise in demand [of pilots]...has caused many medical helicopter operators to drop the minimum number of flight hours they require of pilot applicants." However, of the 22 accidents occurring in 2004 and 2005, the NTSB reports that no pilot had less than 2,000 hours of experience, seven had between 2,000 and 6,000 hours, and 15 (about 70 percent) had more than 6,000 hours. Four had over 10,000.

Not all helicopter transports are made for strictly medical reasons. Many rural counties have only one or two ambulances, and the nearest trauma center is hours away. Sending a patient by ambulance robs that county of ambulance service for the hours that it is gone, so the county often will call a helicopter. And though I agree that some helicopter transports are unnecessary, often that is not evident until after the fact. I think that it is better to err on the side of caution.

Lastly, your magazine should focus on aviation issues. Whether the emergency medical service helicopter industry is necessary, and to what extent, is a medical issue and should be discussed in medical publications.

Jim Croce
Somerset, Kentucky

Bryan Bledsoe replies: The number of accidents I used was derived from NTSB reports, Federal Aviation Administration accident and incident reports, and the Association of Air and Surface Transport Nurses Association Concern Network. For our research, we defined a medical helicopter accident as any incident that significantly damaged the aircraft, resulted in any person receiving an injury that required medical evaluation, resulted in any person being killed, or impacted patient care. According to these criteria, during 2004 and 2005, there were actually 38 accidents and 26 deaths, not the 35 accidents and 23 deaths that I

TAKE THREE

In addition to those listed in "Take Two" (June/July 2006) and on our Web site (*airspacemag.com*), readers recommended these aviation feature films (plot summaries and other information can be found at *imdb.com*):

A GUY NAMED JOE (1943)
ABOVE AND BEYOND (1952)
AIR FORCE (1943)
AIRPLANE! (1980)
AIRPORT (1970)
ALWAYS (1989)
BATTLE HYMN (1956)
BLAZE OF NOON (1947)
BOMBERS B-52 (1957)
BOMBER'S MOON (1943)
CAPTAINS OF THE CLOUDS (1942)
CEILING ZERO (1936)
CHAIN LIGHTNING (1950)
CLOUD DANCER (1980)
DEVIL DOGS OF THE AIR (1935)
DIVE BOMBER (1941)
DR. STRANGELOVE (1964)
FAIL SAFE (1964)
FATE IS THE HUNTER (1964)
FIGHTER SQUADRON (1948)
FLYING LEATHERNECKS (1951)
FOREVER YOUNG (1992)
I WANTED WINGS (1941)
ISLAND IN THE SKY (1953)
JET PILOT (1957)
LEGION OF LOST FLYERS (1939)
MEN WITH WINGS (1938)
MIDWAY (1976)
MOSQUITO SQUADRON (1969)
MURPHY'S WAR (1971)
ONE OF OUR AIRCRAFT IS MISSING (1942)
ONLY ANGELS HAVE WINGS (1939)
REACH FOR THE SKY (1956)
633 SQUADRON (1964)
SPACE COWBOYS (2000)
STRATEGIC AIR COMMAND (1955)
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THE AVIATOR (1985)
THE BATTLE OF BRITAIN (1943)
THE BRIDGES AT TOKO-RI (1955)
THE DAM BUSTERS (1954)
THE GREAT SANTINI (1979)
THE HIGH AND THE MIGHTY (1954)
THE HUNTERS (1958)
THE McCONNELL STORY (1955)
THE PILOT (1981)
THE PURPLE PLAIN (1954)
THE ROCKETEER (1991)
THE TARNISHED ANGELS (1958)
THE TUSKEGEE AIRMEN (1995)
THIRTY SECONDS OVER TOKYO (1944)
VON RICHTHOFEN AND BROWN (1971)

reported in my piece. I apologize for the errors.

Mr. Croce states that many air medical transports are made for other than strictly medical reasons. It seems reasonable that if a region is short one or more ground ambulances, it would be much cheaper and safer to add ground ambulances, instead of using the most complicated, expensive, and dangerous mode of transportation available.

As for Croce's claim that the use of medical helicopters is solely "a medical issue," I would like to remind him that medical helicopters operate under Part 135 of FAA regulations—the same guidelines that apply to commuter and on-demand air taxi operations. Does he feel that a branch of civil aviation that routinely transports customers should not be publicly discussed? That is akin to keeping commercial airline information private. The use of medical helicopters is both a medical issue and an aviation issue.

The Not-Quite-Right Stuff

The obituary of Scott Crossfield (Soundings, June/July 2006) says that Crossfield challenged the accuracy of a scene in the movie *The Right Stuff* that shows an X-15 shaking violently. The movie scene that Mr. Crossfield challenged actually showed the flight of a Bell X-1.

Matt Bauer
Downey, California

Corrections

June/July 2006 Soundings: (1) "Boeing's Team Moscow"—Winnipeg is in Manitoba, not Ontario; (2) "A. Scott Crossfield": The Cessna 210A has a single engine, not two.

"Superduperjumbo": The *Spruce Goose* is not bigger than the A-380. It has a wider wingspan but is shorter and much lighter.

"Glenn Curtiss Slept Here": The proposed park is owned by the B & H, not H & B, Railroad, the train depot is not on the proposed park site, and though a garbage dump had once been on the site, it is no longer there.

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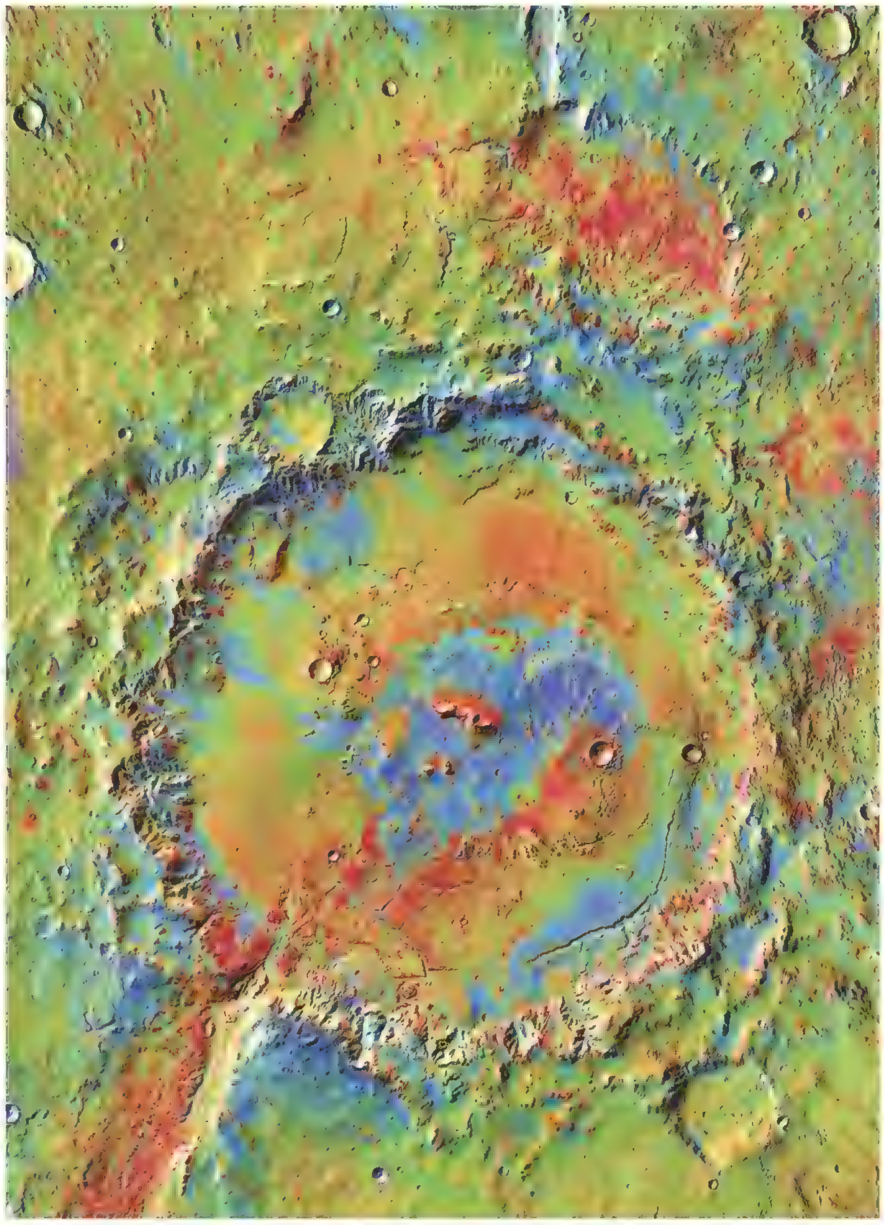
So Many Landing Sites, So Few Landers



NASA/JPL/ARIZONA STATE UNIVERSITY

Mars' Horton Crater beckons. Scientists are intrigued by its diverse assembly of sedimentary deposits.

A new precision landing system will allow NASA's next Mars rover to touch down in 2010 anywhere within a 12- to 24-mile target, giving the spacecraft unparalleled freedom. "There are literally billions of potential landing sites," says NASA planetary scientist Matt Golombek. "We are being given the opportunity to really go anywhere on Mars."

So rich are the opportunities for discovery that Mars Science Laboratory project managers simply asked scientists where they would like to go. During a recent workshop at the Jet Propulsion Laboratory in Pasadena, California, 120 scientists and engineers debated for three days and came up with the top 30, which was passed on to the team planning Mars Reconnaissance Orbiter observations for closer scrutiny. MRO, which can image objects as small as one meter, is braking into its optimal orbit for surveying and is expected to begin scouting Mars Science Laboratory landing sites in January.

Ideally, NASA wants a site that was or is suitable for life and clear evidence to prove it: preserved layers of rock that are exposed at surface level and chemical fingerprints of past water. The rover's mission is not to search for life directly, but to unlock the mineralogical makeup of target rocks and soils. Instruments aboard the rover will be able to identify organic compounds, such as proteins and amino acids, which are essential to life as we know it. The rover also can analyze atmospheric gases associated with biological activity.

"The question we're trying to get out is, Did life develop on Mars, and if it did, what happened?" says Golombek, a co-chairman of the rover's landing site selection committee. "If not, why not? It's a hard question, because we don't even know how it happened on Earth."

The contenders include regions such as Nili Fossae, which may have water-formed clays on its surface, a discovery made by a chemical-sensing spectrometer aboard Europe's Mars Express spacecraft. "There's a nice association between clays and life," says Golombek.

Other sites, such as Gale Crater and Meridiani, have outcrops of layered sedimentary rock, which may show a history of water. Meridiani is where NASA's Opportunity rover in 2004 uncovered evidence of a shallow, salty ancient sea. The only regions off-limits for the new rover are the polar zones. NASA is restricting sites to about 60 degrees north or south of the planet's equator in part to simplify the flight path and because the frozen carbon dioxide ground cover at the poles is not the ideal surface for the heavy rover to tread. Scientists plan three more workshops before a final landing site is selected in 2009.

With no backup rover in the wings, NASA's primary concern is a safe touchdown. Says Golombek, "If you don't land safely, you don't get any science."

IRENE KLOTZ

UPDATE

Cutting-Edge Gossip

According to the London, England *Daily Telegraph*, Rolls-Royce chief executive Sir John Rose noted last May that the company is developing an engine for a supersonic business jet ("Mach 1 for Millionaires," Feb./Mar. 2006). However, he cautioned that the end result is not likely to hit the market anytime soon.

When Dog Is Your Copilot

Maryland pilot Michele McGuire loves taking her mutt Cooper flying, though the first time she did, Cooper was not thrilled. "He would curl up in the back seat," McGuire says. "That's not how he acts normally." She figured that the airplane's noise hurt Cooper's ears. The sane thing would be to leave the dog home, but McGuire decided to get a noise-muffling headset for him.

She enlisted engineer Phil Bare, who lives in North Carolina, to build a series of prototypes to fit Cooper. "We went back and forth, and then it turned into an aesthetic battle," she says. "He had bolts up there that made Coop look like Frankendog." After eight versions, they had one that worked: two ear cups, with connecting straps on top and a chin strap underneath.

So outfitted, Cooper behaved just like a dog in a car: He wagged his tail and smeared his wet nose on the Cessna's windows. The headset was such a success that McGuire is now selling them online (*safeandsoundpets.com*) in small, medium, large, and extra large. "A freakish number have asked for one to fit their cat," she adds.

Other fliers have asked for canine headphones so the pilot could hear Rover pant and bark, and Rover could listen to air traffic control. McGuire says she's not quite sure about that one. "But a fake boom would be cute, wouldn't it? Maybe that will be Phase Two."

PHIL SCOTT

MICHELE MCGUIRE

Cooper enjoys the sounds of silence with his custom-made noise-muffling headphones.

AIR & SPACE INTERVIEW

Stuart O. Witt

GENERAL MANAGER, MOJAVE, CALIFORNIA AIR- AND SPACEPORT

BEFORE LANDING AT MOJAVE, home of Burt Rutan's Scaled Composites and the National Test Pilot School, Stuart Witt, a graduate of the Top Gun Fighter Weapons School in California, flew F-14s and F/A-18s for the Navy and later B-1Bs and F-16Cs for Westinghouse Electric (now Northrop Grumman).

Now that Mojave is a licensed spaceport, what physical or cultural changes will make way for the rocket ships?
In addition to adding more runway, we have upgraded our entire operating handbook. We now train our emergency response crews in different ways, we control large crowds efficiently, we have many new security features, and we handle and store many new types of fuel.

PAIWEI WEI/323SPRINGBOARD.COM

Brevity (and a background in management and lots of flight time) is the soul of Witt.

Other U.S. locales are clamoring for spaceport status. What gives Mojave an edge?
The same reasons that drove the Wrights to Kitty Hawk bring R&D projects to Mojave: Freedom from encroachment of the press, freedom from industrial espionage, and a steady breeze. Dreams are nurtured here. When I explain the lure of Mojave, it's hard to justify the 100-degree days and sagebrush, but very easy to describe the people, their passion, and great ideas.

Many airports are under siege by encroaching development. How will your neighbors respond to your expansion?
We have the general public who enjoy high-desert life, we have the Air Force and Navy conducting daily R&D flight operations and regularly using Mojave Airport to augment their sites, and we have resort neighbors who treasure the serenity of the California mountains and desert. We've completed noise and flow operation studies to determine the effects of adding suborbital spaceflights from Mojave to our 300 aircraft operations per day. All we are really doing is clearing another aircraft for takeoff and an additional glider to land.

Any surprise visitors at Mojave recently?
One day, a Robinson R44 helicopter showed up on our flightline."Where are you headed?" I asked the crew. "The south pole," they said. "We left the north pole two weeks ago!" And I'm always humbled by the many Marines who are World War II veterans walking our corridors, looking at photos and sharing their stories of aerial gunnery training at Mojave Marine Corps Air Station before shipping out for the Pacific.

The Ultimate Layover

The new Fly Lounge, in Washington, D.C., is making quite a splash with an aviation-themed, ultra-exclusive atmosphere. If you can make it past the bouncers—ditch the sneakers, unless they're leather and made by Gucci—you'll have a fine time.

This is the Gulfstream V of night clubs, especially in a town plagued by economy-class joints packed with drunken Capitol Hill interns. Longtime DJ Chuck Koch, 31, opened the club in May with his managing partner, Richard Eidman. Koch flies his Cirrus SR-22 out of Potomac Airfield in Maryland. "My grandfather and my uncle were both pilots," he says. "And I've been a DJ for 12 years. I just meshed my two passions together."

The aviation theme begins with the exterior, with an overhang designed to resemble a Concorde wing. "I had a vision," says Koch. He worked with Washington design firm Hill Enterprises to realize it. Little bags of overly salted peanuts in shiny silver packages grace each table, along with a laminated drink menu designed to look like a seat-back safety card. The walls and ceilings are curved to resemble an aircraft interior, and the "windows" (the club is below ground) look out on a sky generated by plasma screen televisions.

COURTESY FLY LOUNGE

Aircraft-grade aluminum shapes the walls at Fly Lounge, a posh new joint in Washington, D.C., co-owned and designed by a pilot.

Booking a seat can be as challenging (and expensive) as nabbing a first-class aisle seat on a June flight to Paris. If you manage to reserve a table (with bottle service, it's $600 minimum; you order your drinks by the bottle, not the glass) on a weekend evening, a scantily clad "flight attendant" will provide you with bottles of high-end alcohol. Try the Snow Queen vodka for $325. The bottles are served in an "afterburner" filled with ice, lit red from beneath.

Last May, hot-shot fighter jocks arrived in force to demonstrate their skills above the skies of Washington at the annual airshow at Andrews Air Force Base in Maryland. Alas, only a few were cool enough to gain admittance to Fly Lounge. "We're very picky about who gets in," says Koch. The club has room for only 150 patrons. "We want to keep it exclusive."

A night at Fly Lounge is as chic as a red-eye to London in Virgin's Upper Class—that is, if the flight attendants were allowed to turn you away at the gate.

BETTINA CHAVANNE

HEADS UP

2006 Clear Lake Splash-In

Sept. 22-24
Lakeport, CA 95453
www.clearlakesplashin.com
Phone (877) 828-2286

Time for the 27th annual Splash-In, the oldest and largest seaplane gathering in the western United States (see "Jump in a Lake," Apr./May 2006, to learn about its eastern counterpart). The harbor at Skylark Shores will be the base for water operations; landplanes will be based at Lampson Field. Numerous Light Sport seaplanes (a new aircraft category sanctioned by the Federal Aviation Administration) are expected to attend. Family entertainment includes spot landing and water bombing contests, vendors, exhibitors, seaplane rides, seminars, seaplane instruction, and, most important, plenty of hamburgers and hot dogs.

ROGER CAIN

A Grumman Albatross, Mallard, and Widgeon parade over the western United States' biggest seaplane gathering.

The Swiss Breakthrough!! The Thinnest Calendar Watch Ever Made

The Steinhausen engineers set out to make the thinnest, lightest, most beautiful watch in history. After five grueling years of constant research, development and testing, they introduced the Dunn Horitzon Rasierer. At less than two millimeters thick, you can't buy a slimmer model that includes a two-digit calendar. The Europeans lauded it for its sophistication and aesthetic look and design – it was one of the top attractions at the Basel Convention for watches and clocks in Switzerland (the most important annual clock and watch show worldwide for the past 34 years). Italian art schools are using the Dunn Horitzon as an example of the perfect design model. The Japanese praise the Dunn Horitzon for its quality and sophisticated design. And the American consumer paid the ultimate compliment by making it one of our top-selling timepieces.

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The Dunn Horitzon Rasierer is made from stainless steel but has been designed with a special German-engineered alloy that removes almost all the weight, making it so thin that you won't even notice it's strapped to your wrist. And if you have sensitive skin, don't worry. Our gold watch is plated with 24 karats and five microns of gold that will never lose its shine or fade away.

Satisfaction Guaranteed

Your appreciation of the Dunn Horitzon Rasierer is certain to increase over time. We are so confident that you will receive such an abundance of compliments, that as part of our celebration of this glorious introduction, we will include a free Steinhausen patented money clip, a $40 value, with each order. If you are dissatisfied for any reason with the Dunn Horitzon Rasierer, return it and pay only shipping and handling but keep the money clip as our gift.

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Steinhausen's Dunn Horitzon watch is significantly thinner compared to others

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Lindbergh—For Sale

Stanley King started with buttons. An artist, musician, and founder of a lucrative fabric-design business in New York City, King has had the financial wherewithal to buy thousands of pieces of memorabilia relating to some of his favorite subjects: George Washington, Abraham Lincoln, American jazz, and, perhaps most passionately, Charles Lindbergh. In 2002, King donated his vast collection of Lindbergh memorabilia to the National Air and Space Museum, and on June 20, nearly 400 of the artifacts went on display at the Steven F. Udvar-Hazy Center in northern Virginia.

The Stanley King collection has many *Spirit of St. Louis* sculptures.

Born two years after Lindbergh's 1927 New York-to-Paris solo flight, King, as a child, became fascinated by Lindbergh. "Here was a young man who changed the world," he says. Later, a 20-something King bought his first chunk of Lindbergh memorabilia. "There was a little hobby store in Manhattan that I walked into, and they had a bunch of stuff from Lindbergh's 1927 welcome to New York," he says. He happily paid 25 cents apiece for dozens of buttons and ribbons, but that was just the beginning. Lindbergh, flying the *Spirit of St. Louis*, had toured the 48 states following his return to New York, and at every stop, souvenirs were for sale. King soon discovered that Lindbergh had spawned a merchandising bonanza. "There was china," he says. "And the next thing, it's curtain fabric and drapery and tapestry and clothing and pillowcases. And quilting. And I'm saying 'This is unbelievable.' "

King says that during the 50-plus years he has collected all things Lindbergh, he has spent about $200,000. "I've never been shy with something," he says. "If somebody said, 'This is $500,' that was it. I wanted it, and I thought it was important. But I started collecting when those buttons were 25 cents, and then the market moved along. I mean there are things I've paid 10 and 20 thousand dollars for. There's one group of telegrams that were bought from the estate of his lawyer. All the congratulatory telegrams" that were sent after Lindbergh's transatlantic triumph. To find these treasures, King patronized such auction houses as Christie's and Sotheby's, and he regularly peruses the goods available

ARTIFACTS

A glass sculpture of Albert Einstein is back on exhibit at the National Air and Space Museum. Donated by the Steuben Glass Company in 1976, the sculpture greeted visitors to the Museum's Einstein Planetarium. By the mid-1990s, a multitude of cracks forced curators to retire the bust from display. When Steuben's president learned earlier this year that the sculpture was damaged, he asked Peter Drobny, an artist and technician with Steuben and the Corning Museum of Glass, to oversee a corporate-sponsored restoration, which required bringing the original engraver out of retirement.

—Tom Crouch, the National Air and Space Museum's senior curator of aeronautics, manages the Museum's art collection.

ERIC LONG (5)

King never saw a Lindbergh souvenir he didn't want: luggage, cigarette cases, and makeup compacts (opposite) and china, glassware, figurines, and banjos (above).

from the online auction house eBay, where he bought a toy *Spirit of St. Louis* glider, the only example he's ever seen.

Before King sold his textile business in 2003, he lived and worked on an entire story of a building on Fifth Avenue. Half of the space was a studio for King's staff, and the other half was a cavernous apartment dominated by the Lindbergh collection. "I must have had 20 *Spirit of St. Louis*'s hanging from the ceiling," says King. "And volumes of memorabilia" displayed on lighted shelves. "I had weather vanes from farms that were done like the *Spirit of St. Louis.* Imagine people coming up and just absolutely flipping out. And then I'd serve them lunch as well."

As much as King enjoyed living in a virtual museum, he started wondering what he should do with all the Lindbergh stuff. His children didn't want the collection, and King had no desire to sell it. "I said I should give it to some place that it could be shared with a lot of people," he says. His first choice was the Museum, since that is where Lindbergh's airplane is displayed, and aeronautics curator Dom Pisano was delighted to accept. The King collection has 800 major objects and thousands of smaller pieces, including sheet music, menus from banquets Lindbergh attended, and photographs.

Museum specialist Carl Bobrow has spent more than a year cataloging each Lindbergh item. Much of the King collection is now viewable online at *www.nasm.si.edu/collections.* "To work with Lindbergh items is just a treat," says Bobrow. In fact, he has been inspired to write a book documenting the King collection as well as other Lindbergh artifacts.

As for King, he looks forward to making the trip from New York to see his collection on display. He won't come empty-handed: "I must have another 20 items to bring down," he says.

DIANE TEDESCHI

Toy manufacturers churned out a variety of board games and trucks, as well as a spectacular flying *Spirit*.

VISITOR INFORMATION

August 2–30 Summer Concert Series: U.S. Air Force Band Singing Sergeants. The band, which plays big band, jazz, country, and pop, performs each Wednesday from 12:30 p.m. to 1:30 p.m. Gallery 114, Museum on the Mall.

August 26 & September 23 Saturday Star Party. Join National Air and Space Museum staff astronomer Sean O'Brien in observing celestial objects in dark skies unpolluted by city lights. Sky Meadows State Park, Virginia, 7:45 p.m. to 11 p.m. Parking fee: $4 per car; park phone number (540) 592-3556.

Curator's Choice
Occasionally a National Air and Space Museum curator gives a 15-minute talk about an artifact or subject of interest at the Steven F. Udvar-Hazy Center in northern Virginia. Meet at the nose of the SR-71 Blackbird aircraft at 12:20 p.m.

Aug. 3, Spacesuit Android; Aug. 17, Bowlus BA-100 Baby Albatross—A Horse-Powered Glider; Sept. 7, Samuel Langley's Great Aerodrome; Sept. 21, Corona Film Return Capsule.

Location The National Air and Space Museum is located on the National Mall, along Independence Avenue SW, between 4th and 7th Streets, Washington, D.C. The Steven F. Udvar-Hazy Center is at 14390 Air and Space Museum Parkway, Chantilly, Virginia, near Washington Dulles International Airport.

Food The Museum on the Mall has the Wright Place Food Court, which offers selections from the menus of McDonald's, Boston Market, and Donatos Pizzeria. An upstairs cafe serves coffee and pastries. Hours: 10 a.m. to 5 p.m. The Steven F. Udvar-Hazy Center has a McDonald's & McCafe, which serve burgers, salads, muffins, cakes, and coffees. Hours: 9:30 a.m. to 5 p.m.

Except where noted, no tickets or reservations are required. To find out more, visit www.nasm.si.edu *or call Smithsonian Information at (202) 357-2700; TTY: (202) 357-1729.*

A Hard Day's Night

Four decades ago on a mid-winter morning at Larson Air Force Base in Washington state, a cold war routine was being played out by Strategic Air Command B-52D bombers and crews of the 768th Bombardment Squadron (Heavy). Crews were at the end of five days on ground alert, living together in the "mole hole," within sprinting distance of their aircraft. It was "changeover" morning, with fresh crews relieving those coming off alert.

NASM (SI NEG. #00129297)

My crew and one other 768th crew had a mission to fly before going home for a two-day break, then five days of flying before our next ground alert tour. I was a young first lieutenant who, at the moment, was strapped into the navigator's seat aboard a B-52D, call sign Ranger 42. It was January 5, 1966, and a 27-hour workday was just getting started.

In 1961, SAC announced that nuclear-armed B-52s were conducting airborne alert missions. Code-named "Chrome Dome," these flights were a part of SAC's nuclear alert posture for seven years. B-52 units rotated on flying routes over the Arctic and Mediterranean. The idea was to reduce retaliatory response time in the event of a missile attack. To that end, several two-ship formations of armed B-52s were airborne around the clock within striking distance of the Soviet Union.

Most Larson crews flew an Arctic route, and though it was a complex, challenging, and exhausting mission, we considered it routine. On this morning, waiting for takeoff clearance with engines idling, Ranger 42 sat just off the runway and behind Ranger 41, the other 768th B-52 making up our flight of two. Each aircraft carried two 9,000-pound B53 nuclear bombs. Secured in each cockpit was a sealed metal box containing the top-secret "go codes," charts, and target data necessary for the execution of a retaliatory nuclear strike.

One minute after Ranger 41 lifted off the runway, Ranger 42 was rolling. As the pilot slowly advanced the power on the eight J57 jet engines, he made his customary takeoff announcement: "Everybody grab a throttle and run forward." A mile and a half later, we broke ground in the distinctive nose-low B-52 climbout attitude, bumping our way through a patch of the leader's wake turbulence, then fell into two-mile trail formation.

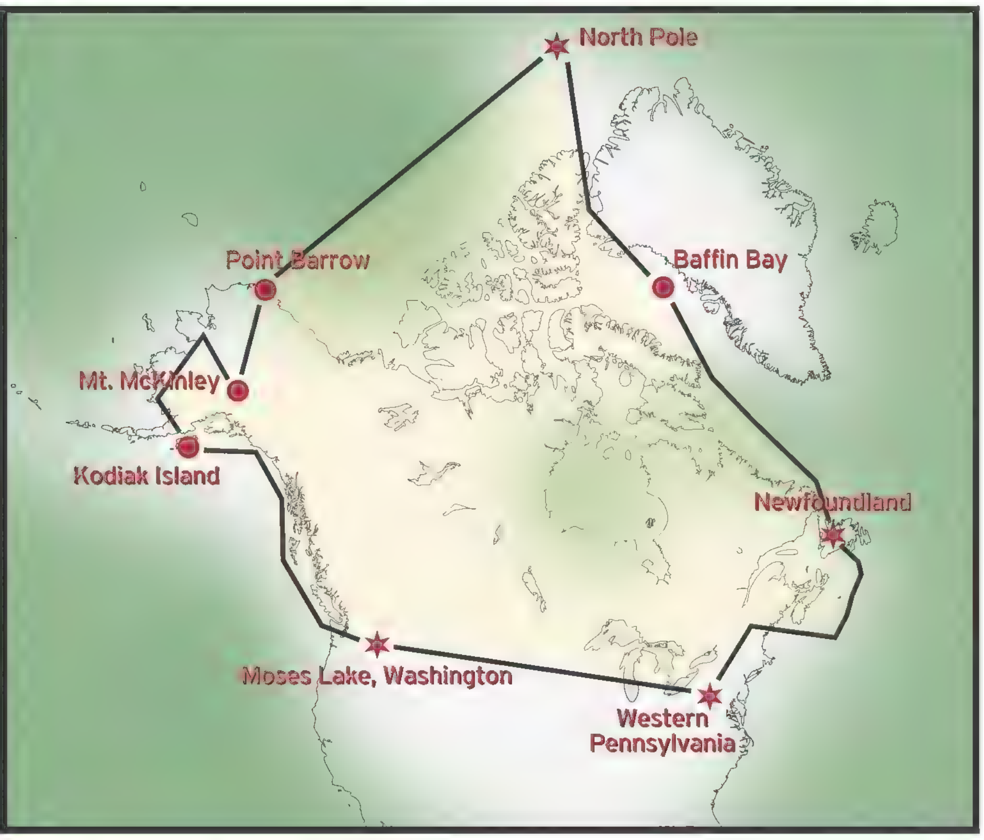
Over Pennsylvania, the flight took up an east-northeast heading for our rendezvous with a pair of KC-135 tankers in the "Black Goat" refueling area off Newfoundland. Each bomber would take on about 12,500 gallons, enough to carry us over the pole and down to our next refueling, over central Alaska.

At 60 degrees north latitude, south of Cape Dyer and the Arctic Circle, it was time to "go into grid"—an air navigation technique used in polar regions where the unreliability of the magnetic compass and the acute convergence of geographic lines of longitude (meridians) close to the pole rule out steering by conventional methods.

On normal polar charts, the convergence of meridians close to the pole causes one degree of change in true course for each meridian passed. This change occurs more rapidly the closer the aircraft comes to the pole. The practical effect of this is that in order to fly a straight course, the aircraft would have to be placed in a constant turn—not good.

To solve the problem, grid

navigation necessitated reorientation of the aircraft's heading reference to a false north, what we referred to as "grid north," by replacing the polar chart with a chart containing a square latitude and longitude grid. Because the meridians on the new grid chart were parallel to the Greenwich Meridian, the angle between grid north and true north could be calculated and a new geographic heading reference established.



Cold war B-52s flew an icy northern route on alert for a Soviet missile strike.

Once this new heading reference was resolved, the aircraft's primary compass was switched to a gyro-stabilized, free-running mode, then simply reset and maintained on the new grid heading.

After passing Thule, we were ready for "coast out" over the ice. It was 400 miles to our turn point at 89 degrees north latitude, where we would begin the 1,000-mile southbound leg headed for "coast in" at Point Barrow. At this point, the only reliable means of navigation was celestial, done by taking star sightings and plotting fixes while flying at seven miles per minute.

Flying over the Arctic had an element of the mystical. Undulating, curtain-like displays of the Aurora Borealis—the Northern Lights—seemed close enough to touch. Every so often, St. Elmo's Fire gave the engine nacelles, wing leading edges, and windscreen pillars a spooky blue glow. Occasional commentary among the pilots and gunner on the marvels of the Arctic night at 41,000 feet were interspersed by the radar navigator's reports of possible polar bear and seal sightings as he surveyed the ice through the optical bombsight, cranked up to maximum magnification for enhanced sightseeing in the bright moonlight.

As riveting as the Arctic show was, I was occupied with making three-star fixes, heading shots, and gyro compass precession corrections. The routine was to shoot and plot each fix, adjust airspeed and heading to stay on time and on track, take a heading shot and reset the heading on the gyro compass, calculate and plot the new assumed position for the next fix, then begin the process all over again every 20 minutes.

After our turn at "89 north," the electronic warfare officer detected friendly and unfriendly Distant Early Warning radars tracking us. He briefly tuned his receiving gear to listen in on the Soviet DEW line guys talking to one another and wondered out loud if they were discussing us. Since I spoke a little Russian, I listened in via an intercom jack to see if I could get the gist of their conversation. Everyone got a chuckle when I told the crew that the Soviet operators were playing chess.

At 200 miles from Alaska's north coast, I took my last celestial fix and the moment of truth—landfall—was upon me. Squinting over my oxygen mask into the orange sweep of the radar scope, I knew that Point Barrow's little cluster of buildings would give a small but distinct return. Although I had been this way before, a twinge of apprehension reminded me of a kinship with maritime navigators of old, who surely had similar feelings as they made landfall after long voyages.

In a few minutes, Point Barrow popped up right where it was supposed to be. When the copilot tuned the radio direction finder's receiver to the local radio station for a confirming bearing, we heard The Mamas and the Papas welcoming us to Alaska with "California Dreamin'."

Our final refueling was with KC-135s from Eielson Air Force Base in the "Cold Coffee" area, abeam Mount McKinley. We had been flying for 15 hours, covering nearly 7,000 miles. At a pressurized-cockpit altitude of 12,000 feet, everyone was a little dehydrated, the coffee was history, the water stale, and our teeth felt like they were growing fur. Only nine hours to go.

After a final lead change, I could relax a little. Tired but not sleepy, I moved up to keep the pilot's seat warm, giving him the opportunity to stretch out on the deck for a nap after his refueling exertions. The electronic warfare officer gave our post-refueling report to the SAC Command Post at Offutt Air Force Base in Nebraska, the radar navigator monitored Ranger 41's electronic beacon on his radar scope to maintain our position two miles behind him, and the gunner started another *Playboy*. I joined the copilot in dining on a couple of semi-petrified pieces of cold SAC fried chicken purloined from the alert facility mess hall 18 hours earlier.

Munching on our drumsticks, we were content. World War III hadn't started and it was beginning to look like the world, and Ranger Flight, might make it through another day. We cruised out beyond the Alaskan west coast, just north of the Aleutian chain, then reversed course, heading toward a turn point off Kodiak Island for the final leg, along the Canadian west coast and home to Larson.

At touchdown, 24 hours and 10 minutes after wheels up, our squadron mates aboard Soapy 21 and 22 were already airborne, taking our place on their own odyssey across the top of the world.

BILL ROBINSON

Nikola Tesla's Curious Contrivance

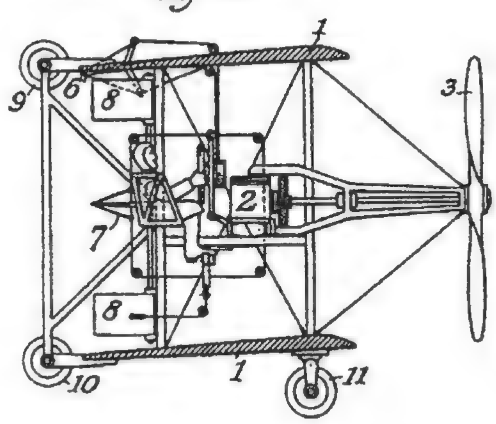
"You should not be at all surprised if someday you see me fly from New York to Colorado Springs in a contrivance which will resemble a gas stove and weigh almost as much."– NIKOLA TESLA, 1913

In the years following the Wright brothers' first flight, anyone and everyone with a daring idea produced a flying machine, from Albert Einstein and his ill-fated wing to Thomas Edison and his box kite-type rotor biplane. "There were a lot of fairly eccentric designs in the patents from this era," says J. Gordon Leishman, professor of aerospace engineering at the University of Maryland. But aviation history apparently forgot the hybrid tilt-rotor/tilt-wing helicopter-airplane that Nikola Tesla dreamed up in 1921—until this summer, on the 150th anniversary of his birth.

Although popular American history has largely ignored Tesla, the Serbian immigrant was heralded as the wizard of electricity in the first half of the 20th century. From development of the alternating current and the use of powerful turbine engines to radio and remote control, Tesla invented big. He installed his electricity-generating machinery at Niagara Falls, thereby creating the Niagara Falls Power Company, and lit the World's Fair in Chicago in 1893 in conjunction with the Westinghouse Company. So significant were his contributions that Tesla's 75th birthday in 1931 made the cover of *Time* magazine. "To this day there's a kind of mystique around this guy that's bigger than life," says inventor Woody Norris, a Tesla fan in southern California, who will soon introduce a personal vertical-takeoff-and-landing aircraft, the AirScooter.

In January 1928, the U.S. Patent Office granted Tesla what would be his final patent, for a "novel method of transporting bodies through the air." He described and sketched an open box-type craft with a tilting propeller and wing that theoretically would enable the vehicle to rise vertically and fly horizontally, though he also suggested a design in which two propellers "coaxially or otherwise disposed" would "revolve in opposite directions," powered by his turbine engine.

Fig. 2.



U.S. PATENT OFFICE

Would Patent #1,665,114 fly? Only in Tesla's dreams, say those in the know.

Contrary to popular Tesla myth, this concept was not the inspiration for vertical-takeoff-and-landing craft, but it appears in hindsight that he logged a few significant first claims. "This may be the first tilt-rotor/tilt-wing concept," Leishman says. Adds Roger Connor, a curator of vertical flight at the National Air and Space Museum, "The theoretical concept is very similar to the Convair XFY-1 Pogo that we saw in the 1950s, the Bell XV-15 in the late 1970s, and in the Osprey today." And Tesla's discussion of using a turbine engine is "astonishingly prescient," Connor says. "In vertical flight particularly, if you don't have a turbine, you're not going anywhere, so he hit the bull's-eye on that one, and to my knowledge this is the first time anyone proposed a turbine on a rotorcraft."

Leishman says it's clear that Tesla did some serious thinking. He considered the issue of control in forward flight, designing his aircraft with ailerons and conventional flight control surfaces. But when it came to hovering, Tesla was hopelessly naive about the vagaries of rotary wing flight. "He missed how long the blades would have to be to give you any kind of meaningful lift and all the issues dealing with stability," says Norris, who encountered the physics first-hand with his AirScooter.

"The other thing that's lacking is a way of compensating for torque reaction, which means it could never be practical," says Leishman. "On a conventional helicopter, you've got a tail rotor that provides the anti-torque." But Tesla "basically left the tail off this thing," Connor points out.

Tesla probably could have gotten airborne with his turbine engine, "but the tendency would be for the body of this machine to rotate in the opposite direction to the propeller," Leishman says. As Norris puts it, "The thing would just spin maddeningly in a circle."

By 1928, Tesla was without a laboratory or funding and headed toward impoverishment, passing much of his time tending to the pigeons in New York City's Bryant Park. He died alone and penniless in 1943 at 86.

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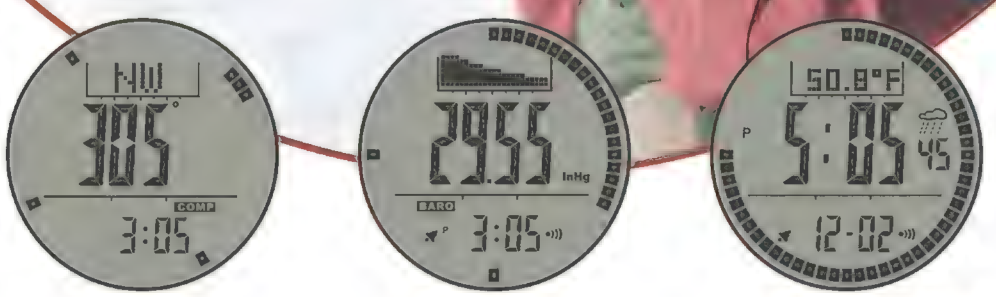

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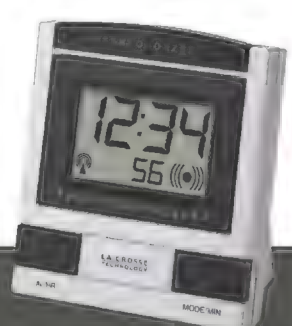

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A new aviation museum preserves Pearl Harbor's past.

WHERE THE

RALPH WETTERHAHN

Pacific Aviation Museum director Allan Palmer points out some of the scars from Japan's surprise attack on December 7, 1941.

The first time I got a good look at Ford Island, in Hawaii's Pearl Harbor, was through the left windscreen of a Cessna 172 on April 23, 1987. I was a member of the Hickam Air Force Base Aero Club, and I was getting checked out in the Cessna by my flight instructor. We entered the landing pattern above the short runway that bisects Ford Island. Though I was busy with throttle, flaps, and radio, I recall spotting the submerged battleship USS *Arizona*, now a memorial to the ship's 1,177 crewmen who lost their lives in Japan's surprise attack on the morning of December 7, 1941. I am a retired military pilot, and coming in at 1,000 feet, I could imagine how easy it was for the Japanese dive bombers and torpedo airplanes to strafe the U.S. naval air station below.

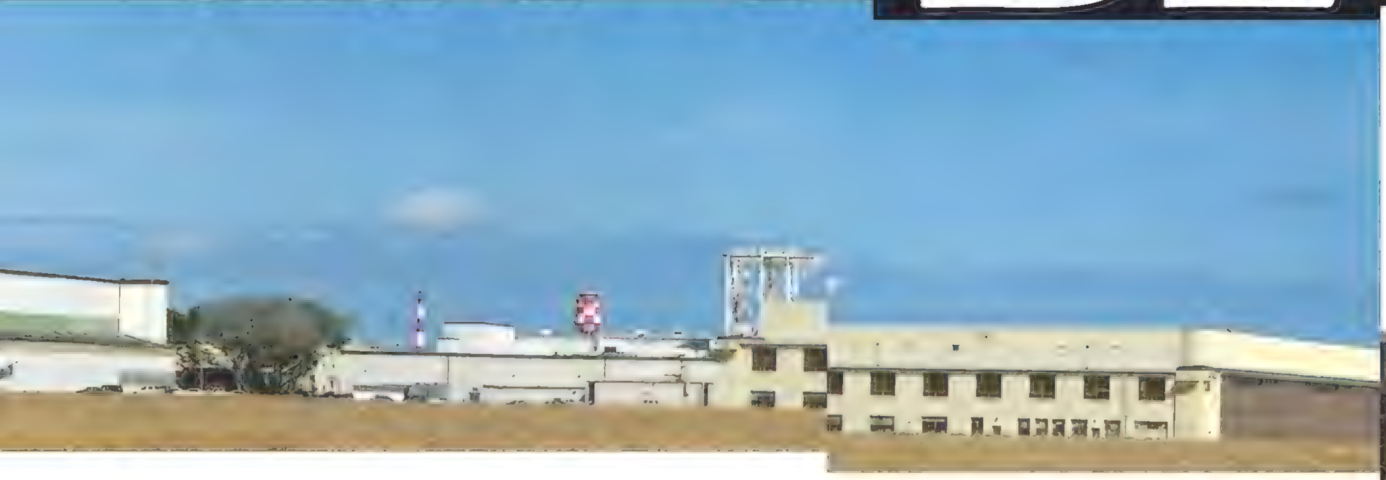
Last September, I was able to see Ford Island up close, as a guest of Allan Palmer, executive director of the soon-to-open Pacific Aviation Museum, which comprises much of the historic air station: an orange and white control tower and three of the surviving hangars. Hangar 37, the first building to be restored, is scheduled to open December 7; it will house several exhibits about the Pacific air battles that took place in the wake of the attack on Pearl Harbor. Hangar 37 will offer amenities that many aviation museums do—a gift shop, food court, flight simulators, and theater. But only at the Pacific Aviation Museum can visitors see the scars of December 7: a bomb crater, strafing pockmarks on concrete ramps and taxiways, and the remnants of two hangars that didn't survive the attack.

Palmer, a former fighter pilot and Vietnam veteran, escorted me to the front of Hangar 79, an 87,750-square-foot building that will eventually house the museum's Korean, Vietnam, and Cold War exhibits (the collection includes everything from a North American F-86 Sabre to a Bell UH-1H helicopter). Weeds have sprouted through cracks in the tarmac, and the facility is in need of repair. Pointing to green

ALL PHOTOGRAPHS COURTESY OF THE PACIFIC AVIATION MUSEUM EXCEPT NOTED

by Ralph Wetterhahn

War Began



Naval Air Station Ford Island today is the site of the new museum. Sixty-five years ago, the island was burning during a two-hour aerial assault that drew the United States into World War II (above).

ABOVE: NATIONAL ARCHIVES

window panes on the hangar door, Palmer asked, "See the bullet holes?"

Japanese strafing runs had left the glass panes full of holes. Several other windows looked as though they had been broken by vandals. "We'll replace the broken panes and those that don't have the original green tint, but leave the ones from the attack as they are now," said Palmer.

Palmer drove past the museum's other two hangars, which will eventually house exhibits. He pulled up a short distance from yet another hangar, still used by the Navy.

"Here is where the Japanese began their attack the morning of December 7," said Palmer. "The Navy's patrol bomber squadron was located here. The Japanese wanted to bomb the seaplanes on the ramp first, because they were the only aircraft that could find [Japan's] carriers, so it was number-one priority. In photos from that morning, you can see a plane burning right over in that direction." We walked a few yards closer to the hangar. "Here's the evidence," he said, pointing at the ground. Two lines of golfball-size holes had been gouged in the asphalt. "The pilot was probably in a bank when he fired," said Palmer. "The machine gun on the [outer] wing made that pattern, and the [inner] wing's bullets hit first, over there." Two distinct strafe patterns were visible, one ahead of the other. I glanced up into the clear blue sky and imagined a Zero in a slight left bank, wings sparkling as the pilot fired his guns.

The next day, I drove to the museum's main office, temporarily located in Honolulu, and met Mike Wilson and Syd Jones.

The son of a test pilot, Wilson is the museum's curator. He had the opportunity to experience aviation first-hand as a commercial pilot before working in the restoration department of the San Diego Air & Space Museum. He joined the Pacific Aviation Museum in June 2005 and takes pride in historically accurate restoration. "Neanderthals in Speedos" is how he refers to improperly restored aircraft. "You wouldn't put up with mistakes like that in a natural history museum," he said, "but it happens all the time in air museums." Wilson's responsibilities involve planning exhibits and verifying the historical accuracy of everything associated with the collection's aircraft.

Jones is the museum's restoration director. He

used to work for Tom Reilly Vintage Aircraft in Kissimmee, Florida, where he helped restore warbirds, including a Boeing B-17 and several North American P-51 Mustangs.

Inside a warehouse at Honolulu International Airport, some of the Pacific Aviation Museum's treasures await transport to their new home. A Stearman N2S-3 Kaydet, covered with a polyethylene sheet, looked as clean as it must have on October 15, 1942, when it rolled off the factory line in Wichita, Kansas. This particular Stearman, serial number 07013, was flown by a future U.S. president. In December 1942, 18-year-old Navy aviator George H.W. Bush flew a solo sortie in the airplane. Years later he recalled his feelings about flying another Stearman: "I was a little scared at first, but the plane was forgiving, and I made it through," he wrote to a reporter for this magazine in 1994.

Honolulu International Airport served as a temporary home for the museum's Aeronca trainer, which was airborne during the attack. Japanese fighters shot up its tail.

From the warehouse, Wilson and Jones led me to an atrium inside the airport. There, in a splash of sunlight, hung an Aeronca 65TC monoplane trainer. Built before World War II, the Aeronca was airborne during the attack on Pearl Harbor. At the time, the trainer was operated by the Gambo Flying Service, and a Gambo flight instructor was teaching his son to fly when a wave of Zeros swept past. It wasn't until after the father and son landed at what is now Honolulu International Airport that they realized the Aeronca's tail had been shot up, damage that is still visible.

During a phone interview after my visit to Ford Island, Palmer tells me that his aircraft wish list includes "certainly anything Japanese theater. A Val dive bomber comes to mind first. There just aren't very many of those. There are one or two still in jungles here and there. But then there's things like Corsairs, P-40s, Hellcats, Betty bombers. We'll acquire as many of those as we can." In the meantime, Military Aircraft of Riverside, California, is making a full-size

NASM (9A00141)

fiberglass replica of a Curtiss P-40 for the museum's Pacific theater exhibit.

Palmer is most pleased with two recent acquisitions: a Japanese Zero fighter and a Grumman F4F-3 Wildcat, "two really centerpiece airplanes that were major combatants during the Pacific campaigns of World War II," he says. The Mitsubishi-designed Zero A6M2-21, built under license by Nakajima, was the same type of fighter that attacked Pearl Harbor, although the museum's Zero rolled out of the factory a year later, on December 14, 1942. This Zero was based in the Solomon Islands, where it flew against American fighter squadrons, including the U.S. Navy's VF-17 "Jolly Rogers," Greg "Pappy" Boyington's VMF-214 "Black Sheep," and the Cactus Air Force of Guadalcanal. More than 20 years after the war's end, Bob Diemert, a pilot and aircraft restorer, recovered the Zero on Ballale Island in the Solomons and took it to Canada, where he rebuilt it. Diemert later sold the Zero to the Commemorative Air Force, which flew the graceful fighter at airshows for 10 years. Of all the aircraft in the collection, the Zero might be Palmer's favorite. "It's a real 'wow' factor for people visiting here, particularly the Japanese," he says, "because they can see something that's been recovered, and is here where it all took place. They can stand out there in the grass near the cracks in the concrete runway and kind of imagine all of this going on all around."

The museum's F4F-3 Wildcat was manufactured in 1943. The U.S. Navy accepted the fighter on April 3 and assigned it to the aircraft carrier USS *Sable*. It's possible the Wildcat and the museum's Zero could have tangled in a Pacific battle or two had the Wildcat not crashed in Lake Michigan during a training flight on June 21. The F4F-3 never saw combat and had only 150 hours on it when John Dimmer brought it out of the lake in 1991 and restored it to flying status. The Wildcat was on display at the Museum of Flight in Seattle when the Pacific Aviation Museum purchased it from Dimmer last December.

In addition to the Zero and the Wildcat, Palmer has rounded up a Douglas C-118, a McDonnell Douglas F-15, a North American SNJ-5B, and a Soviet MiG-15, among other aircraft. These artifacts will no doubt draw a steady stream of aviation fans, but the real attraction of the Pacific Aviation Museum is its historic Ford Island setting.

From left to right: the museum's Grumman F4F-3 Wildcat; curator Mike Wilson (left) and restoration director Syd Jones inspect an architectural model; film producers have long been attracted to the air station and its orange and white control tower; as a young Navy aviator, future president George H.W. Bush flew the Stearman trainer that was later acquired by the museum; five weeks before the attack, Ford Island, in the center of Pearl Harbor, was a hub of activity for the Navy's Pacific fleet.

TOMC

THE NAVY'S FEARSOME FIGHTER RETIRES.

WAS IT THE SIZE? The F-14 was big. At 65,000 fully loaded pounds, it was the heaviest fighter ever to be catapulted from an aircraft carrier. Or was it the fluid maneuverability of an aircraft that large, or its Mach 2-plus speed, or the chest-thrumming roar of two powerful engines? Maybe it was simply the fact that in a movie with one of Hollywood's biggest stars, the Grumman F-14 stole the show. Probably all of those factors account for the Tomcat phenomenon: Though it rarely got the chance to prove its air superiority, the F-14 is wildly popular with aviation enthusiasts around the world.

They have the Soviets to thank. Were it not for the Tupolev Tu-95 Bear bomber and increasingly capable anti-ship weapons, there would have been no need for a supersonic fleet protector. With a radar and missile suite powerful enough to destroy a threat from 100 miles away, the F-14 was built to whup the Bear and its formidable fighter escorts. In its 34-year career, however, the F-14 shot down only five enemy aircraft, four of them Libyan fighters opposing in 1981 and 1989 the U.S. presidents' carrier-backed contention that the Gulf of Sidra was international, not Libyan, waters.

In the 1991 war against Iraq, the F-14 was at a disadvantage. Unlike its Air Force counterpart, the F-15, it had to rely on outside clearance to engage an enemy. It also relied on reputation. When F-14s flew cover, Iraqi aircraft routinely abandoned their stations, leading the Tomcat crews to coin a term for the fighter's AWG-9 radar: "MiG Repeller." Twelve years later, transformed into a strike aircraft by the addition of a targeting pod and advanced avionics, the Tomcat flew 6,500 missions against Iraq between March 21 and mid-April 2003. Its last mission was flown last February, from the USS *Theodore Roosevelt.*

The F/A-18 E/F Super Hornet is taking over the strike role for the Navy. Despite the F-14's superior range and undisputed good looks, the 40 to 50 hours of maintenance it needed for every flight hour pushed it, finally, from Top Gun to Top Gone. >>> THE EDITORS

DAVE PARSONS WITH JOHN CARRIER

A Tribute

The Navy's oldest squadron, the VF-14 Tophatters, was still flying F-14s from Virginia's Naval Air Station Oceana in 1999. Doing the job it was designed for (opposite), in 1982 a Tomcat escorts a Soviet Bear surveillance aircraft away from a carrier in the North Sea.

THOMAS TWOMEY

SOME PHOTOGRAPHS AND STATEMENTS ON THE FOLLOWING PAGES WERE COMPILED FOR THE BOOK *GRUMMAN F-14 TOMCAT: BYE-BYE BABY* BY DAVE PARSONS, GEORGE HALL, AND BOB LAWSON (ZENITH PRESS, 2006) AND ARE USED WITH PERMISSION.

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How the Tomcat Got Its Name

BY NOW THE STORY of Vice Admiral Thomas Connolly and his support for the Grumman F-14 has become a Navy legend. As the deputy chief of naval operations, Connolly famously testified against the General Dynamics F-111B, countering a powerful Secretary of Defense Robert McNamara, who believed an all-service airplane would reduce cost. The F-111B was canceled, and Grumman won a contract to replace it. Historians have written that Connolly's 1966 testimony was a career ender, but it won him immortality in the naming of the F-14. The aviator had flown Wildcats in World War II; his call sign: "Tomcat." Another influential Tom, Admiral Thomas H. Moorer, was the chief of naval operations at the time, and his name may have helped the cause.

PHA GREGORY A. PIEROT, USN

Feathers ruffled, a "Turkey" rests on the deck of the *Harry S. Truman* while a Sikorsky MH-60S Knighthawk hoists in supplies for the carrier population.

Don't Call Me Turkey

AT FIRST I DIDN'T like it when I heard the nickname "turkey." I thought it was disrespectful, until one day I was in the ready room watching a recovery. When you're in the ready room, everything just stops when an airplane is recovered. Everybody's watching the TV screen to make sure it goes okay. So I'm watching the airplane come in, and it has so many moving surfaces—these huge horizontal stabilators that are as big as an A-4's main wing and they move differentially, and the spoilers rise on the wing, and it's flapping and rocking. And I had to admit: It looked just like a turkey.

>>> DAVE "HEY JOE" PARSONS, VF-102, -32, -101

CARRIER OPERATIONS

Airshow

YOU ARE ON THE Landing Signal Officer platform of the USS *Kitty Hawk*, off the coast of California. It's a warm December night in 1993. Out of the starry black sky comes an ungodly roar followed by an enormous slab of a wing and huge vertical stabilizers. Thirty tons of Tomcat hurtles by, eclipsing the stars, trailing fire, feeling for the 3 wire. The beast slams onto the deck and instantly goes to full power (in case the hook misses), which rattles your very bones and literally takes your breath away. The airplane has just conveyed the message, "I am the biggest, baddest Grumman cat ever to fly off a carrier. YOU GOT THAT, you miserable civilian scum?"

>>> PATRICIA TRENNER, AIR & SPACE

TYSON RININGER/TVRPHOTOGRAPHY.COM

Headed home to the USS *Harry S. Truman* in the Arabian Gulf in March 2005, a VF-32 F-14B (opposite) has already dropped the hook. A little closer to the deck of the *Theodore Roosevelt* off the Florida coast, the F-14 above lands with two fuel tanks and a LANTIRN pod. Below: Three 'cats of VF-1 Wolfpack, seen through the canopy of a fourth, prowl the South China Sea in 1982.

Snakes in the Cockpit

BY THE TIME I SWITCHED to the F-14, I had over 1,000 hours and 300 traps in the F-4 Phantom. The F-4 was very stable in the landing configuration compared to the F-14. The Tomcat's swing wing allowed slower, safer approach speeds, but that required more and larger flight control deflections. It looked like we were beating snakes in the cockpit. Day traps were fun. Night traps were different. Some pilots couldn't get to sleep for hours afterward.

One of our first-cruise [radar intercept officers], after a night trap, asked his pilot why it took so long to get out of the cockpit after engine shutdown. The RIO would stand on the flight deck waiting and waiting. The pilot, an experienced combat veteran, explained that he needed time for his knees to stop shaking before he could safely climb down the ladder. The RIO told me he never looked at night traps the same way again— and never asked another pilot why it took so long to get out of the cockpit.

>>> CJ "HEATER" HEATLEY, VF-21

Unmanned Aerial Vehicle

I HAD GOOD AND BAD days in the jet, but I think I was only terrified twice. In 1978, we were chained on the deck near the tower, and Marc "Tag" Ostertag and Tim "Spike" Prendergast were ready to launch. Suddenly, the release assembly fails and they start down the cat in slow motion. Supposedly never happened before or since. Don't you hate it when they say that? Tag lights the burners, but the jet limps off the bow and disappears. Just then the jet's nose raises above the waves, and all we see is the glow of the seat rockets and then two chutes. But wait a minute—there goes the Tomcat, straight up in full afterburner like the space shuttle. Pull that thousand pounds out of the nose and watch out. The thing climbs to about 2,000 feet, flops over on its back, and next thing ya know it's headed straight at us. We're strapped in and waiting to die. It hit the water right alongside the ship. I wasn't sure I was ready to try my luck on the bow cats after that, but we did. My God, the stuff we laugh about now.

>>> MONROE "HAWK" SMITH, CO, TOPGUN, VF-123

HEATER HEATLEY

Second Shift to VP

FOR FIVE YEARS, I was going to school during the day at Brooklyn's Polytechnic University and working as a second-shift electrician at Grumman's Calverton plant. Being second shift, we didn't get to see the airplane fly that often, but we'd get a few glimpses now and then, and that's all it took to keep us pumped up about it.

I remember George Skurla coming onto the factory floor in 1973. [Skurla, later president of Grumman, headed a management shake-up of the F-14 assembly process.] He really wanted to get 54 airplanes out by the holidays, and he'd show up once or twice a week. At first it was intimidating, and I wondered, 'Am I doing something wrong?' But I ended up looking forward to his visits. I never forgot the factory floor.

>>> SCOTT SEYMOUR, PRESIDENT, NORTHROP GRUMMAN INTEGRATED SYSTEMS, AND CORPORATE VICE PRESIDENT

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VF-211 Checkmates form up over the Atlantic on one of their last romps before transitioning to the F/A-18 E/F.

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RADAR INTERCEPT OFFICERS

"Do You Have It?"

COMING OUT OF THE TRAINING COMMAND, where you learn self-reliance as a pilot, I struggled with this notion of the F-14 RIO. I especially disliked the idea that the RIO could fire both ejections seats when operating off a carrier. My plan was that if a RIO ever asked me "Do you have it?" I would either fly us out or eject us both.

That lasted until my first squadron tour with VF-32 in 1976. Launching from the USS *John F. Kennedy*, working on my cool clearing turn off the catapult (always a challenge in a 64-foot-wingspan, 30-ton jet): Rotate, gear up, snap right, change heading, snap left...uh oh. No snap left. No stick movement past center. We stay in our right turn, nose slowly falling through the horizon around 100 feet. There's lots of screaming help coming from the Air Boss over the radio, but his words aren't clear. What I do hear clearly is the voice coming from the back seat: "Do you have it?" To my surprise I answer, "No." The stick will just not go left. To his everlasting credit, while watching the water streak by just under our right wingtip and with his hands on the lower handle, Jerry "Mountain" Argenzio-West gave me a couple more seconds to get the airplane going where it was supposed to with rudder and afterburner. Despite jammed flight controls, we recovered and got the aircraft back aboard ship. With that test, and after 3,000 hours in the F-14, I am convinced it was the pilot-RIO team that made the Tomcat the great classic fighter it was.

>>> STEVE "SPOON" WEATHERSPOON, VF-32

DAVE PARSONS

Opposite: Tomcat office. Right, above: Over the Gulf of Sidra after the April 1986 night raids on Libya, pilot and RIO depend on each other to watch for missiles and traffic. F-14s flew air cover for Air Force F-111s and USS *America* strike aircraft during Operation El Dorado Canyon and stayed on station until sunrise.

BESIDES OPERATING the radar, F-14 RIOs also operated the inertial navigation system; monitored the hundreds of circuit breakers surrounding the back seat that controlled the airplane's electronics, including control surfaces and avionics; did virtually all the talking on the radios; and commanded both ejection seats (in carrier operations). The RIO operated the mission systems and could fire both the Sparrow and Phoenix missiles. Only the RIO could set up and operate the cameras and targeting system.

PILOTS

The Real Top Gun

WHEN DALE SNODGRASS retired from the Navy in 1999 as the world's highest-time F-14 pilot, with more than 4,800 hours and 12 years as an F-14 demo pilot, he was famous for his finesse, his aggression, his relentless pursuit of the unexpected, and even, sometimes, the not-yet-approved—such as formation aerobatics on the wing of old Grumman fighters. But in 1985, at the Pratt & Whitney celebration in Hartford, Connecticut, he was a new demo pilot and few people had seen him fly.

That Saturday was the kind of day when nobody expected much. Cloud base was barely 1,000 feet, the visibility was a misty three miles, and a number of the pilots had already decided not to perform. Snodgrass said, "I'll fly." He was just back from the north Atlantic, where rain, fog, salt spray, and low clouds were the norm.

With the burners lit, the F-14 roared to life, accelerated down the pavement, and lifted just high enough for wing clearance. Then Snodgrass rolled the fighter into a turn so low, so steep, and so tight that anyone who expected minimum weather to produce minimum performance was instantly on alert.

The F-14, which is big, loud, fast, and powerful enough to climb straight up for 15,000 feet doing vertical rolls, is also agile and versatile enough to entertain a sophisticated audience on a minimum weather day, especially in the hands of a maestro. Snodgrass rolled past the crowd gear up, gear down, wings sweeping through a kaleidoscope of designs, from forward like a wide embrace to backward like a plummeting hawk, afterburners lit, speed brakes out, in knife-edge turns, and hard pulls. A tight, low, fast-paced F-14 would have been entertaining on any day, but in Hartford that day, under clouds the color of cardboard, in air dripping with moisture, the demo was something the crowd won't forget. Snodgrass says, "When we cranked around the corner, on the break and in the turns, the airplane would disappear in vapor, encased in a cloud. All you could see was flames coming out of one end and the nose at the other."

>>> DEBBIE GARY, AEROBATIC PILOT

U.S.NAVY

USS *America*, Dependents Day Cruise, Summer 1988: VF-33 Commander Dale Snodgrass' entry pass thrills family members watching from the flight deck.

THOMAS TWOMEY/CHECK SIX

A Crazed Little Kamikaze

I always thought of the Phoenix as a crazed little Kamikaze hanging under your belly. Send it at someone and it's like a mad dog: You are bound to see some bellies after it enters a fight.

>>> TOM "SOBS" SOBIECK, VF-1

Two explosive charges push it away from the aircraft, so when you launch it, you hear "thump, thump." It drops away and you don't see it for a few seconds—but you're so excited, time has slowed and you wonder if something's wrong. Then you see this huge arcing contrail out in front of the airplane. It climbs to about 100,000 feet and you lose sight of it. You just watch for the explosion in the distance. A 1,000-pound missile coming down from 100,000 feet—that's an enormous amount of kinetic energy, never mind the warhead.

>>> DAVE "HEY JOE" PARSONS, VF-102, -32, -101

Opposite: With 46,000 pounds of thrust from two General Electric F110 engines, a Tomcat shows off three tons of AIM-54 Phoenix missiles.

LANTIRN: The Cat Is Back

AFTER DESERT STORM, things looked bad for the F-14 until the Navy fixed it up with a precision weapon delivery system. First built by Martin Marietta in the 1980s for the Air Force F-15E, the Low Altitude Navigation and Targeting Infrared for Night system allowed a pilot and RIO to detect a target on the ground in infrared, lock onto and track it, and drop laser-guided and GPS-aided weapons with deadly accuracy. Now F-14 pilots could fly close to the ground, at night, or in bad weather during precision-attack missions. Introduced in 1996, the Tomcat's version of LANTIRN not only included an infrared sensor and laser rangefinder but added inertial navigation and GPS equipment, improving accuracy. In some ways, the F-14's system was superior to that flown on the F-15E or F-16C; the F-14 RIO had a bigger cockpit display, which resulted in better target recognition. LANTIRN-equipped Tomcats saw action in Bosnia, Iraq, and Afghanistan.

>>> PAUL HOVERSTEN, AIR & SPACE

THOMAS TWOMEY

A pair of swing-wings-in-training: A B-1B Lancer gives an F-14 practice escorting big bad bombers away from carriers. Below: The commander of test squadron VX-5, in his signature black Tomcat, Vandy One, fires a Phoenix in a test.

TED CARLSON/CHECK SIX

GEORGE HALL/CHECK SIX

Pulling Gs, a Tomcat in after-burner streams condensation trails at the wingtips and creates a dramatic vapor cloud above its lifting surfaces.

Shock and Awe

I remember my first flight out of Pax River with a RIO. He fired up that radar, and I nearly fell out of the seat. It seemed like you could see the whole East Coast. I started to get the feeling for the power the Tomcat would bring to the fight.

>>> CURT "DOZO" DOSE, NAVAL AIR TEST CENTER

First time I actually saw the airplane was when I went up to Grumman [for Navy acceptance trials]. I had seen drawings, and we'd been keeping track of it. It looked beautiful. You were just counting the days until you could get the chance to fly it. Down low, going real fast, there was nothing that could keep up with it. And it was rock steady. Just rock steady.

>>> JAY "SPOOK" YAKELEY, COMMANDER, CVW-14, CCG-3

The *Achille Lauro* Incident

In 1985, the U.S. Navy sent F-14s to intercept an Egyptian airliner carrying four Palestinians who had hijacked a passenger liner. After murdering one passenger, the hijackers sailed to Egypt and negotiated safe passage in return for the safety of the remaining passengers.

After the *Saratoga* got word from the Pentagon via the 6th Fleet to find the 737, the carrier's airwing and crew scrambled to fire Tomcats into the darkness. Once we intercepted the airliner, Ralph Zia in the E2 told the Egyptian pilot to proceed to Sigonella, Italy [a NATO base], not his intended destination, Libya. Ralph got your basic 'It's too hard, and who are you, anyway?' Steve "Spoon" Weatherspoon and his RIO Woody Widay got up close, flipped on their lights, and the pilot became much more cooperative. We all know how big the Tomcat looks up close, even to an airliner.

We headed east down the Med at about .88 Mach, cruise speed for the 737 but a gas burner for us. We were covering huge distances and out of direct comms with the ship. The E-2 was rattling and shaking as it drove past its speed limit to stay within radio contact with us. Things got more hectic as we reached Sigonella. The 737 was way too low on his first approach and almost bought it until we flew past him to make him go around. He finally put it down. Thanks to outstanding tanker pilots and the *Saratoga*'s skipper, we hit a tanker on the way home and got safely back to the carrier 500 miles away.
>>> KEN "FROG" BURGESS, VF-74

One hijacker was jailed; two paroled. The last, captured in Iraq in 2003, died in custody.

[SUMMING UP]

"Great-Looking Jet"

I'm flying the Super Hornet now, and it's a very capable jet. The thing is new, and it's as dependable as a Japanese car. Everything works, all the time. But I'm sorry—it just ain't sexy. The Tomcat is sexy. I remember forming up after a fight or something, looking over, thinking, 'Damn, that's a great-looking jet.' The Tomcat is like your 20-year-old cherry Corvette, and the Hornet is like a nice new Accord.
>>> JIM "MOUTH" McCALL, VFA-102


TYSON RININGER/TVRPHOTOGRAPHY.COM

Green shirts are catapult operators; yellow shirts assist the pilot in lining up on the cat; red shirt makes sure the weapons are secure—a costume drama repeated for every launch. Below: Workin' at the 'cat wash.


U.S.NAVY

December 30, 1970: Second Flight

After a hydraulic system failure, two Grumman test pilots ejected from the first pre-production F-14. Neither was harmed.

We were about a half mile short of the runway and 25 feet above the trees. Bill [Miller] quickly initiated the ejection sequence. Firing of the canopy and the two seats took 0.9 seconds as advertised; 0.4 seconds later the nosewheel hit a tree. This episode could have been avoided. During a lab test before the first flight, we had to shut the engines down because the aircraft lost hydraulic fluid. We later found out that a report from the lab was working its way through the system over Christmas, telling us that the failure in the test was a fatigue fracture of titanium hydraulic lines, the same failure experienced during our flight. >>>BOB SMYTH, TEST PILOT

40 Miles of Wiring

BEFORE BECOMING A U.S. Navy officer, Lieutenant Commander Walt Winters spent 12 years as an electrician assigned to F-14s. What made the Tomcat such a high-maintenance aircraft (40 hours of maintenance per flight hour), says Winters, is the "40 miles of wiring that was inside of it. Old and brittle, the wires would constantly break and snap" from the stress of launch and landing.

After almost every flight, a team of 12 to 15 maintainers, including at least two electricians, two airframe specialists, and two engine mechanics, would descend upon an F-14 after the pilot had parked it on the flight deck. During flight operations, the team had only 60 minutes to check the Tomcat and ready it for its next launch. Only if a fix would take hours, such as replacing an engine, was an F-14 taken to a lower deck.

To park an F-14, the pilot had to put the wings into "oversweep," a setting five or six feet beyond the swept-back position they could assume during flight. The wiring needed to command the wings into oversweep broke—a lot. "Sometimes you would have to jury-rig it," says Winters. "And you're doing this while you're on top of the airplane. It's still running, the engines are hot, and the [flight crew] are still in there. You've got panels open, and the boss is yelling over the loudspeaker, 'Get the wings back!' Jets are landing right beside you at 150 miles an hour. And taking off. And sometimes it's raining."
>>>DIANE TEDESCHI, AIR & SPACE

BOB LAWSON/CHECK SIX

On June 2, 1981, VF-24 Fighting Renegades flew a perfect diamond on their return to NAS Miramar in San Diego—because they could.

U.S.NAVY/JESSICA DAVIS

Engine Trouble

THAT BUSINESS ABOUT FLYING the engines instead of the wing, that was really true with the TF30 [the F-14's original engine]. Any aggressive move you wanted to make, you had to worry about how the engines would like it. Like you had to ask their permission.

>>> HANK "BUTCH" THOMPSON, VF-11

FIND OUT MORE

www.airspacemag.com

MORE TOMCAT TALES and museums where F-14s have found a home are on the Web site.

Parade Rest

WE'VE FLOWN AIRPLANES to museums all over the country. People are goingto be able to eyeball these beauties for a long time. We had one going to Allentown, Pennsylvania, to a VFW display there. I spent two full days talking to permit people. I could not get them to believe the size of the jet, that you can't fold the thing up any less than 33 feet across. The main gear was wider than some of the roads we needed to use. Then they insisted we move it from the airport at 10 a.m. We told them we always do this after midnight because of traffic. Nope—10 or nothing. We shut down Allentown cold. Everyone got into it, made a parade out of it. And the display is magnificent—up on a cliff over the city, all lit up, lots of flags flying. Go see it.

>>> BILL "TACO" BELL, VF-14, -101, -102, -41

TYSON RININGER/TVRPHOTOGRAPHY.COM

Maintainers on deployment near Iraq (above, left) repair antenna wiring. A favorite at airshows, the F-14 flew its last demo at NAS Oceana in 2005.

How Things Work: Swing W

BY JOE PAPPALARDO
ILLUSTRATIONS BY JOHN MACNEILL

IN THE 1960S, U.S. NAVY STRATEGISTS WANTED AN AIRCRAFT THAT COULD EFFICIENTLY CRUISE AT SUBSONIC SPEED, MANEUVER WELL IN HIGH-SUBSONIC DOGFIGHTS, ACCELERATE TO ABOVE MACH 2, AND YET REMAIN STABLE DURING SLOW LANDINGS ON AN AIRCRAFT CARRIER. CONSIDERING THESE DEMANDS, THE GRUMMAN AEROSPACE CORPORATION GAVE THEM IN 1972 THE F-14 TOMCAT, A FIGHTER THAT COULD CHANGE THE SWEEP OF ITS WINGS DEPENDING ON THE WIDELY VARYING SPEED REGIMES.

BOB LAWSON COLLECTION/ NORTHROP GRUMMAN

The Tomcat could fly even with its wings in an asymmetrical position, as shown in this demonstration flight, but pilots weren't trained to fly the configuration.

A variable-sweep wing imitates nature. To glide or slow down, birds extend their wings; to speed up, they tuck them close. But designing those capabilities into a metal airframe, using nuts, bolts, and gears that would mimic a bird's muscle and bone, took decades of work by aircraft engineers.

The first aircraft capable of varying the sweep of its wings in flight was the Bell X-5, an experimental aircraft used by NASA in the 1950s to test wing angles. It was not the prototype of an operational aircraft, but a testbed to explore the aerodynamic effects of variable-sweep wings. Some of the design and even some parts were cannibalized from the Nazi-engineered Messerschmitt P 1101, a variable-sweep wing aircraft that never flew and was captured by U.S. troops in 1945.

Researchers found that as the X-5's wings swept from a 20- to a 60-degree angle, the airplane's center of gravity and center of pressure changed, requiring the entire wing assembly to move toward the nose in order to keep the aircraft stable. To achieve the 40-degree difference, rails inside the fuselage moved the wings about 27 inches forward. It took 20 seconds to complete the change—longer if the electronics malfunctioned and the pilot was forced to hand-crank the wings.

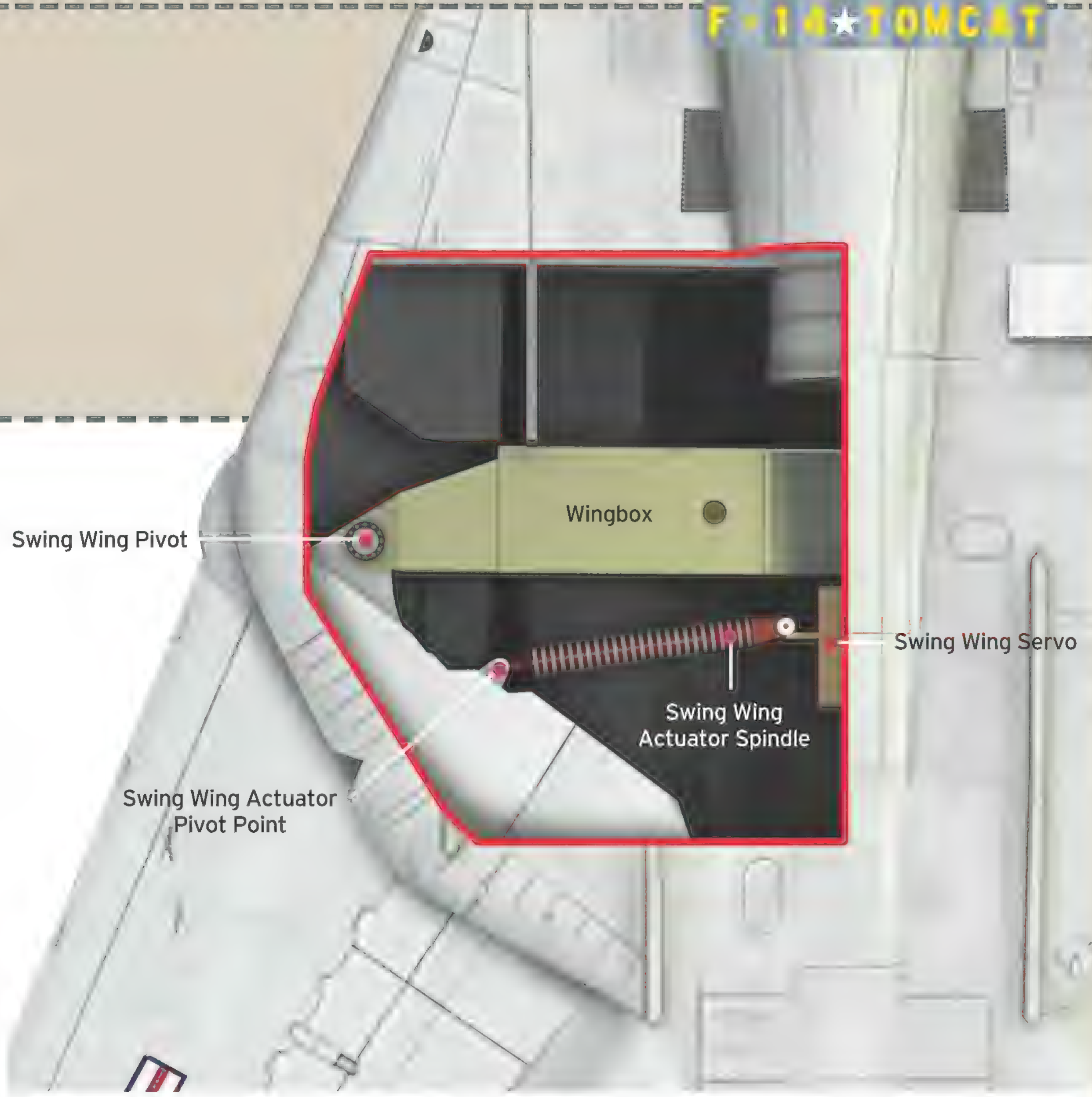
Higher-degree angles in those days presented their own challenges; they tended to make the aircraft more unstable, and the X-5 was notorious for its inability to recover from a spin. In 1953, Air Force Major Raymond Popson was killed when his X-5 spun into the ground, wings in a 60-degree position.

Three decades later, variable-sweep wings became the distinguishing feature of a new aircraft to be flown by both the U.S. Air Force and Navy, the General Dynamics F-111 Aardvark fighter-bomber. The engineering lessons from the F-111 would help create the F-14.

"The aircraft itself was very complex, and we built it without models or simulations," recalls Chris Clark, who worked on the Tomcat as chief test engineer for Air Test and Evaluation Squadron 23 at Naval Air Systems Command (NAVAIR).

The F-14 Tomcat's wings could sweep in flight to 68 degrees (left) for supersonic flight or 20 degrees (right) for slower speeds. On an aircraft carrier, the wings could sweep even farther aft to reduce the Tomcat's footprint.

ings



The Swing Wing Actuator Spindle, a ball screw driven by a hydraulic motor, moved the wing at its pivot points.

"A lot of it boiled down to slide rules and hard paper calculations."

The Tomcat's wings could sweep from 20 to 68 degrees. That translates to the wingspan shrinking from 64 feet to 38 feet. The transformation occurred automatically, with the onboard Standard Central Air Data Computer (SCADC) using altitude and Mach number to determine the appropriate wing angle. The F-14 was the only aircraft in NATO that used a computer-controlled, fully automatic sweep. The SCADC activated the hydro-mechanical system that actually moved the wings and optimized wing positions for altitude and speed, but a Tomcat pilot could manually override the system in the event the SCADC did not work.

Each wing of the Tomcat was driven by a single actuator that could sweep at eight degrees a second. A hollow, crossover shaft of aluminum alloy kept the wings in synchronization. The shaft was riveted into an assembly that connected the left and right wing sweep actuator gearboxes. NAVAIR personnel say there have been only two failures of the crossover shaft in 30 years of F-14 operations in the Navy. In both cases, the aircrews landed safely.

The wings themselves were mounted to a titanium structure, called a wing box, that ran across almost the entire dorsal side of the fuselage and was connected to the wings at two pivot points upon which they rotated.

When the wing retracted, about 25 percent of its trailing edge tucked beneath an overwing fairing, which left a gap between the aft section of the wing and fuselage. Inflatable canvas bags attached to the fuselage closed the gap. The bags also provided a smooth contour to blend the wings' trailing edges and the aft fuselage, allowing a smooth flow of air.

Each wing had a hydraulic motor that moved it either forward or aft. In flight, moving the wings forward required less hydraulic power than moving them back. The hydraulic flow needed to move the wings forward was about 15 gallons per minute and was handled by a fixed displacement pump. The flow needed to move the wings aft was about double that, and was accomplished with a variable displacement pump. The reason for the mismatch was that the positioning of the wing pivot in relation to the wing's center of pressure made it easier to unsweep than to sweep.

On the F-111, the pivot locations were relatively inboard, resulting in excessive trim drag at transonic and supersonic conditions. Tomcat designers were not going to repeat that mistake.

"In those days, [the Navy] wanted high-altitude maneuverability," says Tom Lawrence, a NAVAIR aerodynamics expert who evaluated this capability for the Tomcat. "If you had the wing pivots closer to the fuselage, you get a very large shift in the center of pressure" when the wing changes its angle of sweep. That could lead to the kind of instability that killed Raymond Popson in the X-5.

Designers attached the Tomcat's wings so that the pivots were located at the most outboard position possible, at 8 feet, 11 inches from the fuselage centerline. The result: When the airplane changed shape, less of the wing was actually sweeping.

Though technology improved, the wing design remained basically the same, but Grumman replaced parts of the wing assembly with composite materials better able to handle heat and stress. The airplane's role changed from chasing fast Soviet interceptors to supporting U.S. ground forces with bombing runs, and the Tomcat began showing its age.

"Back in the 1960s there was a need to vary the airplane's geometry," says Captain Don Gaddis of Naval Air Systems Command, a former Tomcat pilot and current program manager for its replacement, Northrop Grumman's F/A-18 Hornet. On the F/A-18, "we've learned how to optimize the wing design so that the aircraft can carry out its functions" without changing geometry.

IRAN'S AIR FORCE FLEW F-14s TO TELL SADDAM: "KEEP OUT!"

Persian Cats

BY TOM COOPER

FIVE YEARS BEFORE THE 1979 Islamic Revolution transformed Iran, Shah Mohammad Reza Pahlavi, a pilot who had earned his wings in 1946 flying a British Tiger Moth, arranged for Iran to purchase 80 Grumman F-14A Tomcats and 633 Hughes AIM-54 Phoenix missiles for $2 billion. (The Iranian deal is credited with saving the F-14 program, which Congress had stopped funding, and by some with saving the Grumman Corporation from bankruptcy.) Iran became the only country besides the United States to fly the big fighter. How useful the F-14 was in the eight-year war that Iran fought against Iraq following the revolution has been a matter of controversy. Many U.S. military analysts have dismissed the significance of airpower in the conflict, but the testimony of the Iranian Tomcat pilots paints a different picture.

Information about the Iran-Iraq air war is difficult to come by. It is impossible to tabulate, for example, how many air-to-air victories were scored by Iranian F-14s because air force records were repeatedly tampered with during and after the war

FARZAD BISHOP COLLECTION

for political, religious, or even personal reasons. Even today, most Iranian pilots will speak about their experiences only on the condition of anonymity. Several pilots quoted here insisted on pseudonyms for their protection.

What is known is that in the 1970s Iran needed an air superiority fighter that could end incursions into its airspace by Soviets flying MiG-25Rs, and the F-14 was up to the job.

By 1979, 120 pilots and radar intercept officers in the Iranian Imperial Air Force (IIAF) had been trained in the United States and Iran, with 100 additional personnel still in training. Simultaneously, maintenance technicians were trained at Pratt & Whitney and Hughes on the engines, avionics, and weapons systems.

"We trained with many U.S. Navy pilots [who have, over the years] 'shot down' U.S. Air Force and Israeli F-15s and F-16s almost at will in all [training] exercises,"


NORTHROP GRUMMAN

Special delivery: Until they landed in Iran, F-14s retained their U.S. markings. Below: Iranian F-14 pilots were part of an air force that endured 12-hour combat air patrols, a brutal regime, and a ruthless enemy.

recalls Colonel (then-Captain) Javad. "They trained us well."

Before the arrival of the F-14s in Iran, a giant air base was built in the central Iranian desert. Khatami Air Base, named after legendary IIAF commander-in-chief General Mohammad Khatami—killed in a paragliding accident in 1975—was to become the main hub for F-14 operations in Iran. By late 1978, 284 Phoenix missiles were also delivered, including 10 ATM-54A training missiles, and the IIAF launched a series of live-fire tests.

"The AIM-54 was truly a deadly system," says Farhad, a former pilot. "During the testing in Iran, we tracked an AIM-54A at Mach 4.4 and 24,000 meters [15 miles] before it scored a direct hit on the target drone. This large and hefty missile had no snap-up or snap-down limits, and could maneuver at up to 17 Gs."

Because of the chaos and violence surrounding the removal of the shah from power, 27 F-14 pilots left Iran in 1979. This number included all but two of the original cadre and 15 pilots still in training. Javad was one who stayed. He was arrested by a close friend at gunpoint, in front of his family. When the war with Iraq began, he was released.

Javad recalls that pilots were not the only ones in danger during those turbulent days. "When the Americans left, many of our technicians went with them," he says. "Some [who stayed] were jailed, several were murdered by the new regime."

To make matters worse, "Hughes technicians had sabotaged 16 AIM-54As at Khatami Air Base before departing for the U.S.," says Captain Rassi. News reports at that time, he says, implied the whole fleet had been sabotaged and that all the Phoenix missiles had been rendered useless.

"In fact," says Rassi, "all the other AIM-54s were safe in their sealed storage/transport cases, and permanently under guard, in underground bunkers at Khatami. Ironically, later we repaired all the 16 rounds damaged by Americans—[with] parts stolen from the U.S. Navy."

Tensions between Iraq and the new Islamic government in Iran escalated. By September 1980, the two countries were engaged in minor border skirmishes.

With Iraq becoming more bellicose by the week and despite chaos in the Iranian military chain of command, what was now the Islamic Republic of Iran Air Force worked hard to return its F-14s to service. Most of the 77 surviving airframes were not operational, or at least had non-functioning radars, while their crews lacked fresh training and experience. As a result, when it came to intercepting Iraqi aircraft, F-14 units had come to rely heavily on ground control. Within a few days of the first clashes with the Iraqis, a dozen or so F-14s were back in service, flying patrols along the border.

The first kill by an F-14 was scored even before the Iran-Iraq war officially began. On September 7, 1980, an Iraqi Mil Mi-25 Hind helicopter (an export version of the Soviet Mi-24 attack helicopter) was shot down with a 20-mm Vulcan cannon. Just six days later, the first AIM-54 kill followed: Major Mohammad-Rez Attaie shot down an Iraqi MiG-21 while he was patrolling an area over which Iraqi reconnaissance aircraft had been especially active in previous days.

The most intense periods of air combat were the first two months of the war, which began September 22. Captain Javad, who was involved in the early actions against the Iraqi air force recalled, "There was little on the ground to stop the massed Iraqi Army from rolling east...[however,] our air force intercepted Iraqi fighters over the border, bombed the Iraqis on the ground, and launched air strikes deep into enemy airspace."

Their F-14s equipped with the AWG-9 pulse Doppler radar, the Iranian pilots could hit an enemy aircraft from 100 miles away, but the pilots also appreciated the airplane's fighting abilities close in. Ma-

FARZAD BISHOP COLLECTION

A modified Boeing 707 offers fuel to an Iranian F-5, F-4, and F-14. Below: The F-14 patch bears the phrase "Anytime, Baby" in Farsi.

jor Farhad recalls the airplane's maneuverability: "The capability of the F-14A to snap around during the dogfight was unequalled.... After only 100 hours of training, I learned to pitch the nose of my Tomcat up at a 75-degree [angle of attack] in just over a second, turn around, and acquire the opponent either with Sidewinders or the gun."

Despite some 1,000 air-to-air engagements between 1980 and 1988, air battles were not a deciding factor in the war. According to retired U.S. Air Force Colonel Ronald Bergquist, a former Middle East specialist, rather than sacrifice their fighter aircraft in combat, both air forces used their fighters as deterrents, in much the same way that the superpowers at the time used their nuclear arsenals. Neither side "could depend upon having a secure enough source to ensure a continuing balance between losses and replacements," Bergquist writes in his 1988 monograph, *The Role of Airpower in the Iran-Iraq War.* Unlike Israel and Egypt in 1973, he says, Iran and Iraq in 1980 had no allies and, unable to replace their losses, had to conserve their fighters. "If they're pressed to the wall, they'll use what they have to," he says. "But if they aren't, they'll just hold them back."

The Iran air force concentrated on its ability to act as a deterrent, and used its F-14 Tomcats to defend strategically important installations, primarily Iran's main oil-exporting terminal at Khark Island.

"During the first few weeks [of the war, the Iranians] did a good job of deterring Iraqi air power and actually forcing Iraqis to at least consider the fact that Iran could attack," says Anthony Cordesman, the Arleigh Burke Chair in Strategy at the Center for Strategic and International Studies in Washington, D.C. "But that faded relatively quickly."

Iran at first attempted to keep some 60 Tomcats in operational condition, but intensive flying and lack of qualified maintenance personnel—not the lack of spare parts, as is commonly believed—forced it to scale back the number of operational F-14s to 40 by 1984, and to 25 by 1986.

On the other hand, the AIM-54 Phoenix missile was deployed only sporadically at the beginning of the war, and then more frequently in 1981 and 1982 until the lack of thermal batteries suspended the use of Phoenix missiles in 1986.

"Deployment of the AIM-54 requires a good cooperation between pilot and radar intercept officer," says Hashemi. "Some pilots have had a problem to accept this fact, and there were many discussions, mainly because we have had great pilots but very few good RIOs."

During the war, Hashemi fired four AIM-54s against the Iraqis. His first missile, shot in July 1982, was directed at a group of Iraqi MiG-23 Floggers attempting to intercept a lone Iranian F-4E that was returning from Baghdad to Iran. "As luck would have it, on this day the closing speed of the Iraqi MiG-23s brought them within the 'kill box' of the Phoenix I fired," says Hashemi. "When the missile hit the lead MiG, it disappeared from my radar along with his wingman.... The MiG-23 was not the fighter the Iraqis had hoped for. It could not outmaneuver any of our fighters and we have had very little respect for them on a one-to-one basis. We were concerned only when facing large numbers of Iraqi MiG-23s, later during the war. The most impressive thing about the MiG-23 was its ability to rapidly accelerate when we chased them—but it could not outrun an F-14."

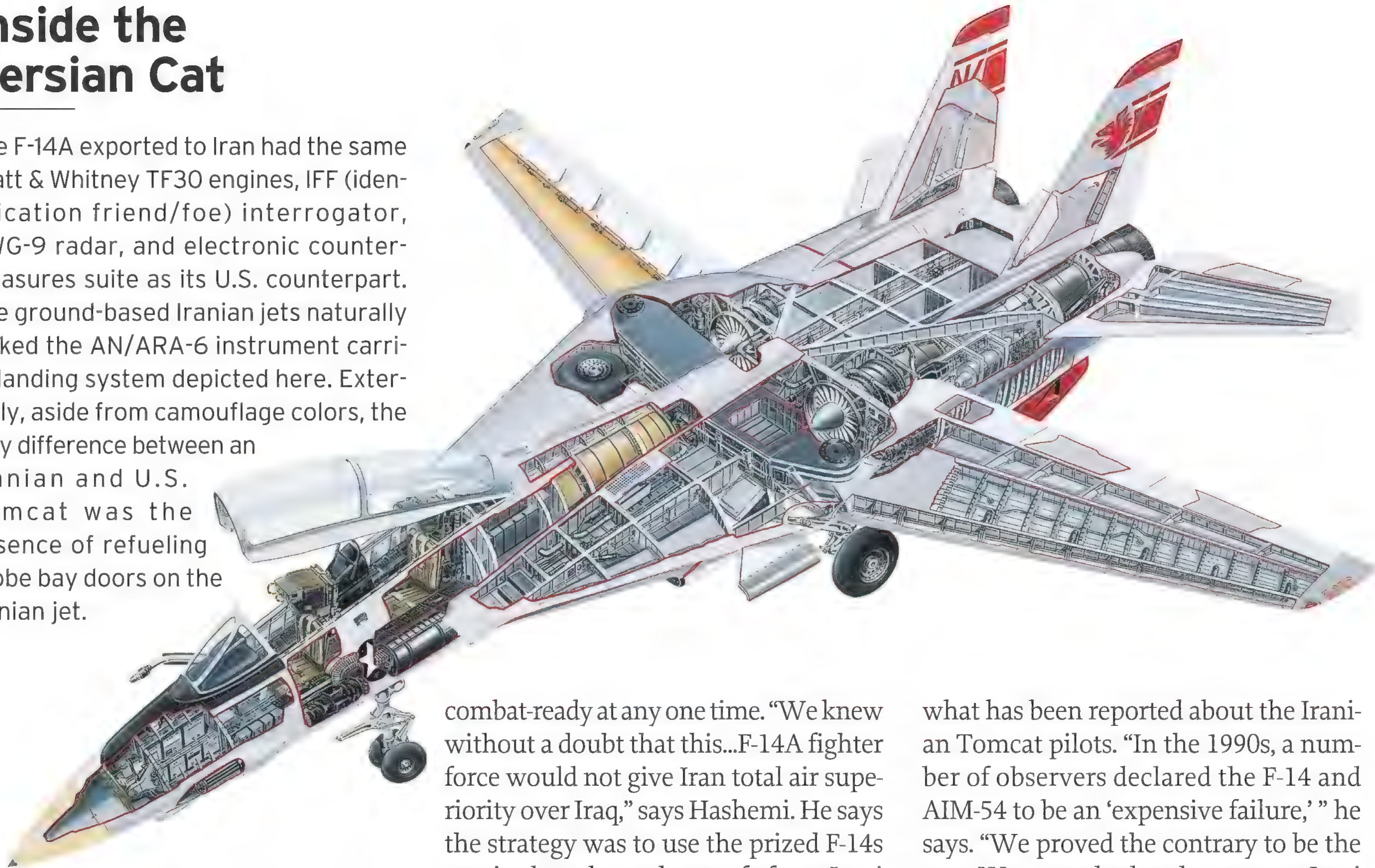
"THE MOST IMPRESSIVE THING ABOUT THE MIG-23 WAS ITS ABILITY TO RAPIDLY ACCELERATE WHEN WE CHASED THEM – BUT IT COULD NOT OUTRUN AN F-14." – CAPTAIN HASHEMI

Some of the most spectacular air battles of the war—many of them between Iranian F-14s and French-built Iraqi Dassault Mirage F1EQ fighters—involved Iraqi attempts to cut off Iranian oil exports and the Iranian defense of the oil refining and exporting infrastructure.

The Iranians suffered heavy losses in the first few months of the war, forcing them to slow their flight operations to conserve their remaining assets. Under those circumstances, even successful air-to-air engagements had only temporary significance. When F-14s were sent up to do battle against the Iraqis, the deploy-

Inside the Persian Cat

The F-14A exported to Iran had the same Pratt & Whitney TF30 engines, IFF (identification friend/foe) interrogator, AWG-9 radar, and electronic countermeasures suite as its U.S. counterpart. The ground-based Iranian jets naturally lacked the AN/ARA-6 instrument carrier landing system depicted here. Externally, aside from camouflage colors, the only difference between an Iranian and U.S. Tomcat was the absence of refueling probe bay doors on the Iranian jet.



JOHN BATCHELOR

ment usually deterred the Iraqis from flying into that area for several weeks. One or two Iranian Tomcats could force a formation of Iraqi fighters to abort their mission or jettison their ordnance before reaching the target.

"I heard many times during [and after] the war how the air force...had let Iran down or how we should have done [things] differently," says Captain Hashemi. "Our F-14As were used only as...interceptors as they were experts for that job." On average, about 40 percent of the F-14 fleet was combat-ready at any one time. "We knew without a doubt that this...F-14A fighter force would not give Iran total air superiority over Iraq," says Hashemi. He says the strategy was to use the prized F-14s sparingly to keep them safe from Iraqi surface-to-air missiles but to have them ready for any strike force that invaded Iranian airspace.

Recalling his interrogation of an Iraqi Mirage F1EQ officer shot down by Iranian Tomcats in February 1986, Major Kazem, a former Iran F-4 pilot says: "Without hesitation, this man told me that he 'knows the IRIAF was left with only some 20 [Northrop] F-5s and a dozen or so F-4s, and no operational F-14s and that all our remaining fighters were poorly flown.' I had to keep myself from explaining [to] him the hard fact that his flight had just been shot to hell by a 'poorly flown' and 'non-existing' IRIAF F-14A."

Thinking back on his experiences during the war, Javad has been bemused at what has been reported about the Iranian Tomcat pilots. "In the 1990s, a number of observers declared the F-14 and AIM-54 to be an 'expensive failure,' " he says. "We proved the contrary to be the case. We not only shot down many Iraqi fighters, but we forced hundreds of Iraqi formations to abort their missions before reaching the target."

Iraqi pilots seemed to have learned respect for the F-14. They faced the aircraft again during Operation Desert Storm, begun only three years after the United Nations-mandated cease fire ended the Iran-Iraq hostilities. U.S. F-14 pilots who flew the fighter on escort and photo reconnaissance missions in Iraq reported that Iraqi aircraft would break off an approach once the Tomcat's AWG-9 radar fired up.

Today, there are still an unverifiable number of Tomcats, overhauled and upgraded with indigenously developed systems, in the Iranian air force.

Below: Tomcat crews performed thorough preflight checks to ensure their AIM-54s would hit their targets, like this Iraqi MiG-21 (right), downed in September 1980.

FARZAD BISHOP COLLECTION (2)

The Grumman Cats

56 YEARS OF NAVY TRADITION | ILLUSTRATIONS BY PAUL DIMARE | TEXT BY BRIAN NICKLAS

GRUMMAN'S FIRST FIGHTERS for the U.S. Navy were barrel-chested biplanes, known only as the F2F and F3F; they had no nicknames, much less the feline names that became near-synonymous with Grumman's Navy fighters. For the company's fourth Navy fighter, sandwiched between the successful F4F Wildcat and F6F Hellcat, Grumman engineers came up with the twin-engine F5F, nicknamed "Skyrocket." Although the F5F exhibited good flight characteristics, the Navy was concerned that the fighter was too heavy. Grumman didn't get a production order, and one wonders if the F5F might have succeeded had it too sported a cat name. Still, the quality of the Long Island-produced airplanes was such that in 1942 Vice Admiral John S. McCain Sr. (grandfather of U.S. Senator John McCain) said, "The name 'Grumman' on a plane or part has the same meaning to the Navy that 'sterling' on silver has to you." To many, sterling silver wasn't a tough enough image, and over the years, the term "Grumman Iron Works" has been used to give the company's long line of attack and fighter aircraft an image of robustness.

GRUMMAN F4F WILDCAT ^ ^ ^

The Wildcat first took to the air on September 2, 1937. Although records show it to be a successful fighter, during World War II it was outclassed in several areas (maneuverability, climb speed, and service ceiling) by its nemesis, the Mitsubishi A6M "Zero." But American pilots overcame the Wildcat's shortcomings with tactics, such as the Thatch Weave (developed by Lieutenant Commander Jimmy Thatch), a criss-cross pattern flown by a pair of F4Fs to cover each other against attackers. General Motors' Eastern Aircraft Division also built Wildcats, under the FM-2 designation. In fact, more Wildcats were built by Eastern than by Grumman. A float-equipped version, known as the Wildcatfish, was tested, but the rapid expansion of land bases and of the escort carrier fleet ended the need for an amphibious airplane. (Britain's Royal Navy also flew the fighter, dubbing it the Martlet.)

FM-2 SPECS

Span 38 ft. 0 in.	**Max Speed** 332 mph
Length 28 ft. 11 in.	**Normal Range** 900 mi.
Height 9 ft. 11 in.	**Ceiling** 34,700 ft.
Empty Weight 5,448 lbs.	

GRUMMAN F6F HELLCAT ˅ ˅ ˅

First flown on June 26, 1942, the F6F was powered by a Wright R-2600 engine. Early in production, however, Grumman switched to the Pratt & Whitney R-2800 to increase the Hellcat's power. The F6F showed its prowess and superiority over the Japanese Zero early on, and Navy Hellcats turned the First Battle of the Philippine Sea into a famous naval victory for the United States. The Hellcat holds the distinction of being flown by more U.S. aces than any other aircraft. Hellcats shot down more than 5,100 airplanes, with F6F losses numbering 270. Hellcats also flew combat missions in the European theater of the war, when Britain's Royal Navy started flying the fighter in 1943.

F6F-5 SPECS

Span 42 ft. 10 in.	**Max Speed** 380 mph
Length 33 ft. 7 in.	**Normal Range** 945 mi.
Height 13 ft. 1 in.	**Ceiling** 37,300 ft.
Empty Weight 9,238 lbs.	

GRUMMAN F8F BEARCAT ˄ ˄ ˄

The F8F entered service just as the war ended, so no Bearcats saw combat against the Japanese. Although it was a superlative aircraft, the rise of jet fighters ended the Bearcat's career as a U.S. fighter almost before it began, and most F8Fs were withdrawn from service before the Korean War. The French military and the Royal Thai Air Force flew Bearcats until 1963. The F8F also became an air racing legend.

F8F-1 SPECS

Span: 35 ft. 6 in.	**Max Speed:** 434 mph
Length: 27 ft. 6 in.	**Normal Range:** 1,105 mi.
Height: 13 ft. 8 in.	**Ceiling:** 38,900 ft.
Empty Weight: 7,070 lbs.	

GRUMMAN F7F TIGERCAT

Initially designed as a twin-engine carrier-based fighter, the Tigercat revealed a problem maintaining directional stability when it was first flown on November 3, 1943. After Grumman improved the design, the F7F became a favored radar-equipped night fighter and attack aircraft for the U.S. Marine Corps. The F7F also proved to be a decent platform for the launch and control of drones. After the war, civilian users added belly tanks to operate Tigercats as firebombers.

F7F-3 SPECS

Span 51 ft. 6 in.
Length 45 ft. 4 in.
Height 16 ft. 4 in.
Empty Weight 16,270 lbs.
Max Speed 450 mph
Normal Range 1,200 mi.
Ceiling 40,700 ft.

GRUMMAN XF10F-1 JAGUAR

The world's first variable-sweep-wing fighter (although the Messerschmitt P1101 and Bell X-5 preceded it as variable-sweep research aircraft), the XF10F was first flown on May 19, 1952, in a short hop that revealed stability and control problems and an inadequate powerplant. The wing-sweep mechanism would be fine, however, and in later years the knowledge gained from the Jaguar was applied to the F-111 Aardvark and F-14 Tomcat. Only one XF10F was completed: It and the nearly complete second airframe ignominiously ended their days as arresting-barrier test airframes.

XF10F-1 SPECS

Span, extended 50 ft. 7 in.
Span, swept 36 ft. 8 in.
Length 54 ft. 5 in.
Height 16 ft. 3 in.
Empty Weight 20,426 lbs.
Max Speed 710 mph
Normal Range 1,670 mi.
Ceiling 45,800 ft.

GRUMMAN F9F PANTHER/COUGAR

On November 9, 1950, during the Korean War, the Pratt & Whitney-turbojet-powered F9F Panther became the first Navy jet to shoot down another jet (a MiG-15) in combat. Later in the war, Ensign Neil Armstrong of the Navy's VF-51 squadron (yes, that Neil Armstrong) ran into a cable over North Korea, an encounter that sheared off six feet of his wing. Armstrong managed to fly to a base, so he could eject over friendly territory. In a departure from the military's usual practice, the F9F designation was retained even after the aircraft was transformed into the Cougar: In 1951, the Panther's straight wing was replaced with a wing swept back 35 degrees. The redesign improved the performance of the F9F and led to a long service life, with F9Fs flying into the 1970s.

F9F-6 COUGAR SPECS

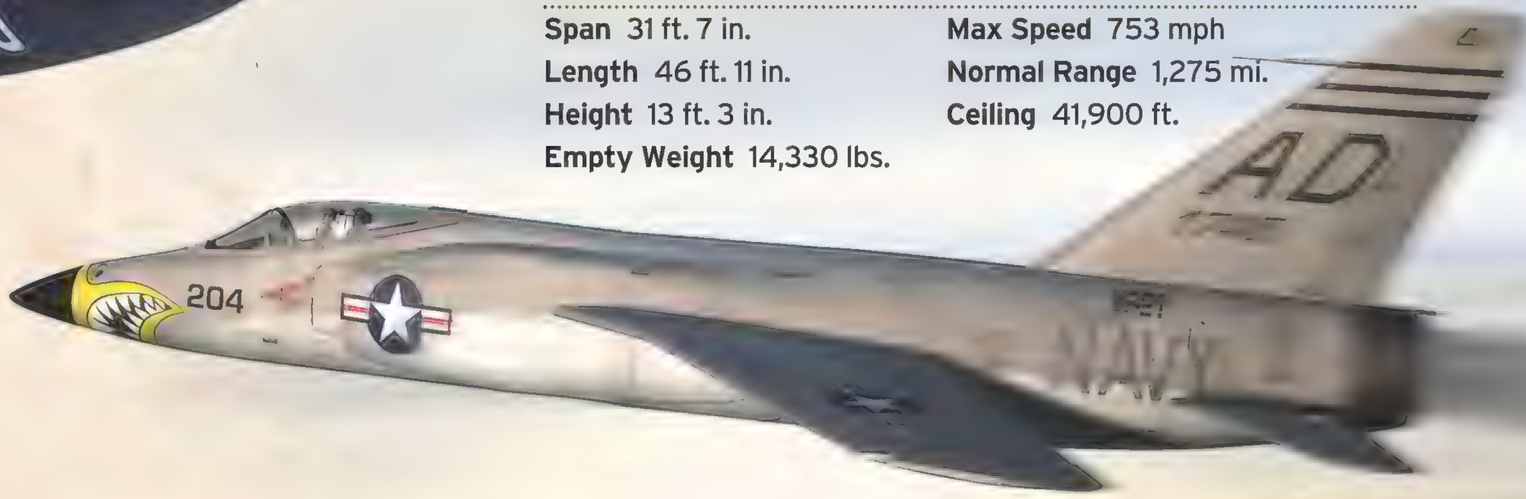
Span 34 ft. 6 in.
Length 40 ft. 10 in.
Height 12 ft. 4 in.
Empty Weight 11,255 lbs.
Max Speed 654 mph
Normal Range 932 mi.
Ceiling 44,600 ft.

GRUMMAN F11F TIGER

Although developed as a result of experience with the Panther and Cougar, the F11F was yet another fighter of the 1950s that suffered from the immaturity of early jet engine technology. Initially appearing with a short nose, the Tiger gained a sleeker look with a nose that was made more pointed in order to house radar. Ultimately, the Tiger ended up a radar-less day fighter, and it was quickly superseded by more capable jets. The F11F shone, however, with the Blue Angels demonstration team, which flew it from 1957 to 1969.

F11F-1 SPECS

Span 31 ft. 7 in.
Length 46 ft. 11 in.
Height 13 ft. 3 in.
Empty Weight 14,330 lbs.
Max Speed 753 mph
Normal Range 1,275 mi.
Ceiling 41,900 ft.



F14D SPECS

Span, extended 64 ft. 1.5 in.
Span, swept 38 ft. 2.5 in.
Length 62 ft. 8 in.
Height 16 ft.
Empty weight 41,780 lbs.
Max speed Mach 1.88
Normal range 1,842 mi.
Ceiling above 53,000 ft.

1. "Calvin and Hobbes" ©1995 Watterson. Dist. by Universal Press Syndicate. Reprinted with permission. All rights reserved.

2. F-14 Tomcat watches, made by Retro Gifts for Pilot Wear.

3. *The Final Countdown*; poster from The Picture Desk (*picture-desk.com*), Kobal Collection/ Paramount.

4. *Top Gun*; poster from The Picture Desk (*picture-desk.com*), Kobal Collection/ United Artists.

5. *Macross II: The Movie*. DVD, ©2000, Manga Entertainment, Inc. (*www.manga.com*).

AIR & SPACE SALUTES THE F-14 ★ TOMCAT

Star Quality

THE F-14 IN POP CULTURE.

SURE, THERE WERE OTHER POINTY JETS out there, but the F-14 Tomcat was the one with a gift for show business. Its breakout performance was, of course, in *Top Gun.* In exchange for script approval, the U.S. Navy let the filmmakers use carriers, pilots, and F-14s to create extraordinarily realistic flying scenes. (Years later, some of the footage was used to jazz up "JAG," a TV series about a Tomcat-pilot-turned-Navy-lawyer.)

Though *Top Gun* made the F-14 a star, it wasn't the Tomcat's first movie appearance. Six years before, F-14s had been used in *The Final Countdown,* but in that time-travel story, the Tomcats had to share camera time and airspace with World War II Japanese Zeros.

Beyond visual glamour, the Tomcat had complexity, making it fun to write about and read about. After flying F-14s, James Huston went on to write thrillers like *Flash Point* that were fat with scenes of Tomcat combat. Likewise, ex-Navy pilot Stephen Coonts packed his novel *Final Flight* with all sorts of expert-level Tomcat trivia.

More fanciful were the Japanese *anime* (animation) TV shows and movies that made use of the F-14. Some depictions took liberties. The Macross series' "VF-1 Valkyrie" was a Tomcat with sensible features added, like wings that swept back 90 degrees for storage.

Perhaps the most uninhibited F-14 fantasy in popular culture was a 1995 installment of the "Calvin and Hobbes" comic strip, in which little Calvin envisions a *Tyrannosaurus rex* flying a Tomcat in a hunt for herbivores. Bill Watterson's brilliant drawings say it all: Flying an F-14, even a dinosaur looks sharp. >>> THE EDITORS

6. David James Elliott as Harmon "Harm" Rabb Jr. in "JAG" on CBS. Photo from Landov LLC (*landov.com*).

7. *Final Flight* by Stephen Coonts. 387 pp., Doubleday, 1988.

8. *Flash Point* by James W. Huston. 579 pp., Avon Books, 2000.

9. "F-14 Tomcat" for Game Boy Advance (flight combat simulation), Majesco Games, Virtucraft Ltd.

Stronger than Dirt

LUNAR EXPLORERS WILL HAVE TO BATTLE AN INSIDIOUS ENEMY—DUST.

BY TRUDY E. BELL

ANOTHER LUNAR DAWN, and the powdery dust on the moon's surface begins to stir. Without a breath of wind, the finest motes swirl across the ancient landscape as electrostatically charged dust grains repel one another. Larger grains join the dance in a line that stretches more than 3,000 miles from the lunar north pole to the south pole, along the edge of advancing daylight.

Within hours the dance has become frenzied and vertical, with microscopic grains hurtling miles overhead, the tiniest ones flying the farthest, until the weak lunar gravity stops their rise and pulls them back to the dusty surface. Instead of resting there, many jump up to begin the dance anew, surrounding the moon with a veritable atmosphere of dust—glassy, abrasive, toxic grit that could spell "No Trespassing" to future explorers.

Under a cloudless blue Colorado sky, I accompanied seven scientists, a graduate student, and an education specialist as they toiled up the shifting sands of the tallest dunes in North America. At 8,200 feet above sea level, the intense sunlight scorched our skin even though it was October, and in the thin air, the exertion left us panting. The incessant wind quickly smoothed away our footprints. We were in the Great Sand Dunes National Park and Preserve, but it felt as though we were alone on Mars.

And that was the idea.

We were there to study the problems awaiting NASA engineers planning the next generation of lunar outposts and Mars expeditions. Four of the scientists carried miniature Mars rovers that looked like the kind of radio-controlled toy you might find at RadioShack. They had thought about bringing

NASA's one spare of the Sojourner rover from the 1997 Mars Pathfinder expedition, "but the commercial truck chassis were far cheaper," explained team leader Masami Nakagawa, an associate professor of mining engineering at the Colorado School of Mines in Golden. Each of the model trucks had been modified for this expedition: transmissions geared down, engines souped up, the body of one turned into a rotating auger for digging in the sand.

For two eight-hour days under the broiling sun, scarcely breaking for granola bars or water, the scientists took turns at the radio controls to put the rovers through their paces. The vehicles were sent climbing the steep dunes until half-buried by avalanches, while cameras and a crude duct-tape tape measure (the real thing had disappeared in the soft sand) documented their progress, or lack thereof. "Hey, I think sand and dust finally jammed the transmission!" exulted grad student Jared Reese, holding aloft the auger vehicle, which had finally refused to budge, even with a freshly charged battery.

Celebrating when the equipment *stops* working? That was in fact the purpose of this NASA-sponsored "Dust-Off": to court Murphy's Law. "Over the next two days, our interdisciplinary team can get a direct feel for how invasive dust is," explained Nakagawa over the first night's dinner, at the Great Sand Dunes Oasis restaurant. "We want to look at lunar and Martian dust mitigation from a systems engineering viewpoint."

By "dust," Nakagawa doesn't mean house dust. Most of the stuff that collects on furniture is actually organic material like dead human skin cells, pet dander, and pollen grains. For the most part, it's soft:

The powdery lunar soil was great for making footprints, but was a problem for astronauts like Charlie Duke, shown here during the Apollo 16 mission in 1972. It got in their eyes and throats, and clung stubbornly to every surface.

Wipe it off with a cloth and it won't scratch polished wood. And it's usually not thick. Even an attic corner that hasn't been swept in years can accumulate less than an eighth of an inch.

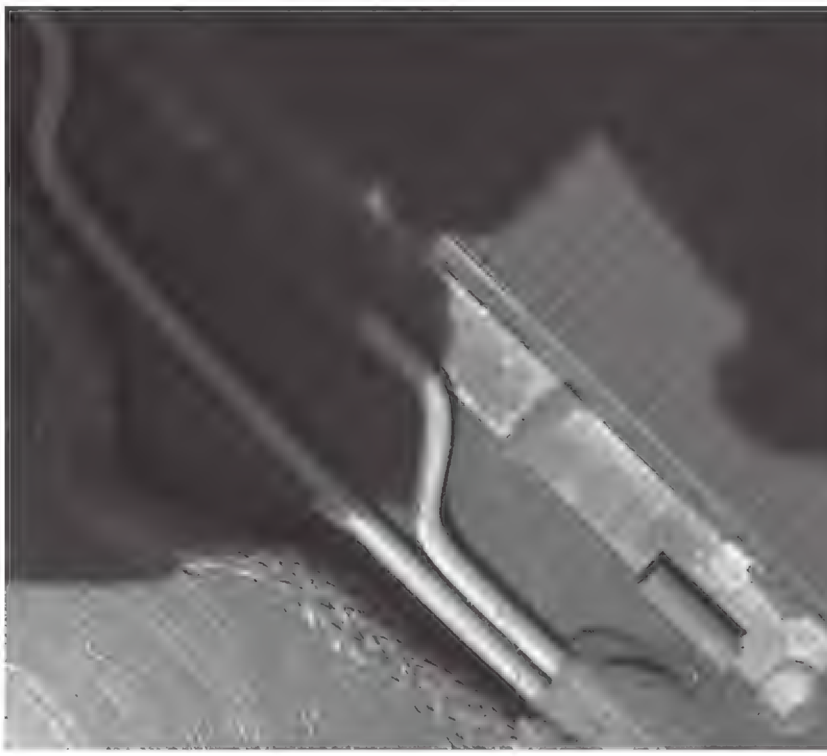
On Earth, the closest equivalents to lunar and Martian dust are the choking storms that sometimes blow west from the Gobi Desert to blanket Beijing with millions of tons of ultrafine particles. In 1980 powdery volcanic ash fell an inch deep hundreds of miles from Washington's Mount St. Helens, and "white outs" of alkali gypsum dust swept the Nevada playa just after the 2002 Burning Man arts festival. But even these aren't good analogs. In terrestrial deserts the atmosphere is too dense, the soils too humid, the plants too numerous, and the weathering from wind and water too prevalent to match conditions on the moon or Mars.

Lunar dust is razor-sharp grit made of inorganic stone and powdered glass. It was formed over hundreds of millions of years by micrometeorites slamming into the moon at high velocities, fracturing lunar rocks into shards and melting the sand into glass. The Apollo astronauts who trod the inches-deep regolith (the preferred term for extraterrestrial dirt) discovered what a nuisance it could be. Wipe a spacesuit's sun visor, and it scratched the protective layer of gold. Get dust into the spacesuit's joints, and it fouled the attachments and seals. Try to brush the grit off a spacesuit before reentering the lunar lander, and its sharp edges dug into the fabric. Track it inside the habitat, and it became airborne. Breathe it in and mucous membranes swelled shut ("I didn't know I had lunar dust hay fever," commented Apollo 17 geologist-astronaut Jack Schmitt at the time). Go back out, and the graphite-black dust had so darkened the white spacesuits ("Looks like you guys have been playing in a coal bin," quipped mission control during the Apollo 16 mission) that the fabric absorbed rather than reflected the murderous sunlight, overheating the astronauts' life support systems.

And that's just the moon.

On Mars, the dust may be corrosive and poisonous too. Martian soil is expected to be a strong oxidizer (think of powdered bleach or lye) laced with heavy metals such as hexavalent chromium, the carcinogen in the movie *Erin Brockovich*. It's also, as engineers operating NASA's Mars rovers have learned, magnetic. Photographs taken by Spirit and Opportunity show Martian dirt, reddish with oxides of iron, coating magnets on the vehicles. On the moon, glass in the regolith is filled with microscopic beads of pure iron—so-called nanophase iron. In both places the dirt is likely to stick to anything with an electromagnet, including motors and electronics.

A mere two days in the Colorado dunes was enough to convince me of the insidious mechanical challenges that dust will present to future astronauts and their machines. The windborne grit scoured our skin raw, sifted into hair and zippers and shoes, messed up the transmissions of all four rovers, and jammed the buttons of cellular phones.



NASA

NICOLE MCGEE/AEROSPACE EXCHANGE

Dust-ologist Masami Nakagawa test-drives a model of a Mars rover in Colorado's Great Sand Dunes park. After a year on the Martian surface, solar panels on the Spirit rover (right) were coated with a fine layer of grit, which degraded their performance.

Even on the airless moon, the dirt doesn't lie still. Astronauts in lunar orbit aboard the Apollo 8, 10, 15, and 17 spacecraft repeatedly observed and sketched what they variously called "bands," "streamers," or "twilight rays" for about 10 seconds before lunar sunrise or sunset. The drawings are reminiscent of the slanting rays that filter up through clouds during sunsets on Earth. Some scientists chalked the phenomenon up to light reflecting from dust suspended above the lunar surface, but others remained unconvinced: Without an atmosphere, how could dust be suspended above the moon? Even if the particles were kicked up by, say, a meteorite impact, they would quickly settle back to the surface.

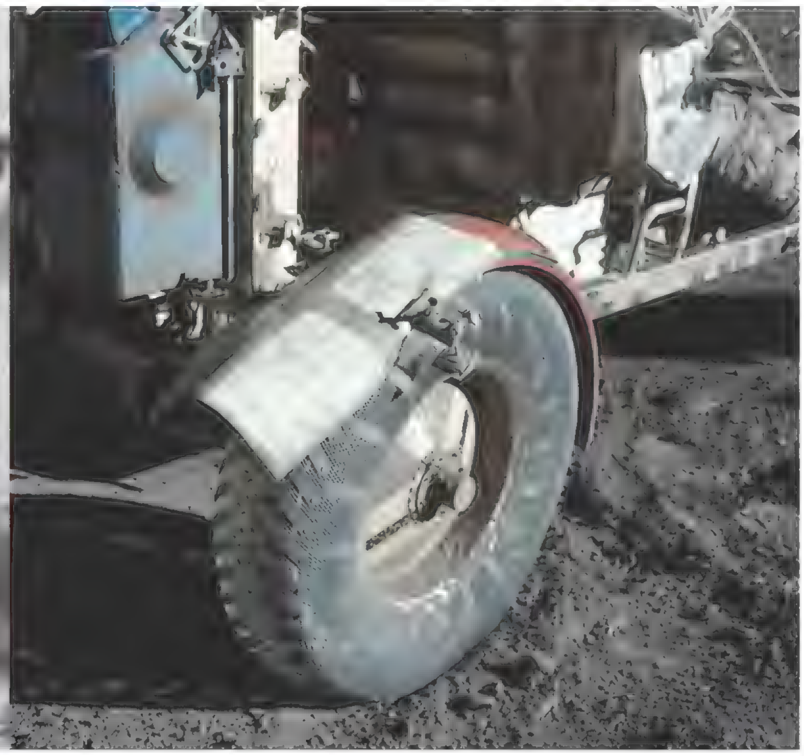
They may be tiny, but lunar dust particles (below) aren't fluffy; they're sharp and abrasive. On the moon, the Apollo astronauts had to protect their equipment. During the Apollo 17 mission in 1972, Gene Cernan and Jack Schmitt even had to jury-rig a fender to control the dirt that the moon buggy's wheels sprayed up.

It wasn't until last year that Timothy Stubbs and his colleagues at NASA's Goddard Space Flight Center in Greenbelt, Maryland, came up with an explanation, which they called the "dynamic fountain" model. In a drinking fountain, the arc of water from the spout appears suspended in one position, but the water molecules are constantly in motion. Similarly, according to Stubbs, microscopic grains of lunar dust are constantly leaping from the surface and falling back again due to a weird phenomenon unknown on Earth: electrostatic lofting.

Just as rubbing a balloon against your shirt creates a static charge that can levitate the hair on your head, lunar dust particles with opposite charges will attract each other, and like-charged particles will repel. How does the dust become charged? On the moon's sunlit side, solar ultraviolet and X-ray radiation beats down relentlessly, knocking electrons from atoms in the lunar soil. The electrons escape into space, and positive charges build up on the lunar surface. The tiniest motes of dust—just a few hundred-thousandths of an inch in size—are repelled from the rest and launched upward, some reaching miles above the surface. Lunar gravity eventually pulls them back down, but electrostatic repulsion kicks them off again. The process is repeated over and over to form a tenuous "atmosphere" of moving dust particles.

The same happens on the lunar far side, which is bombarded by solar wind particles flowing around the moon—except that the net charge is negative since the solar wind is mostly electrons. Data from the 1998 Lunar Prospector mission suggests that the electrical potential might amount to hundreds of volts on the night side, even higher than on the day side, possibly launching dust particles to higher velocities and altitudes.

Evidence supporting the dynamic fountain model may be buried in old data from the Lunar Ejecta and Meteorites experiment, left on the moon by Apollo 17 in 1972. LEAM had three sensors that could record the speed, energy, and direction of tiny particles. The experiment was designed to look for fallout from lunar meteorite impacts, as well as material raining down from comets or interstellar space. But in a classic case of serendipity, "LEAM recorded a high number of particles every lunar sunrise," recounts Gary Olhoeft, professor of geophysics at the Colorado School of Mines, "mostly from east or west rather than from above, and mostly much slower than expected." Even stranger, a few hours after every lunar sunrise, LEAM's temperature rocketed up so high—near that of boiling water—that the instrument had to be turned off because it was overheating. Olhoeft and others now suspect that dust lofted from the moon covered the LEAM, darkening



OPPOSITE: COURTESY MASAMI NAKAGAWA; LEFT: NASA

THE APOLLO ASTRONAUTS WHO TROD THE LUNAR SOIL DISCOVERED WHAT A NUISANCE IT COULD BE. WIPE A SPACESUIT'S SUN VISOR, AND IT SCRATCHED THE PROTECTIVE LAYER OF GOLD. GET DUST INTO THE SPACESUIT'S JOINTS, AND IT FOULED THE ATTACHMENTS AND SEALS.

its surface so the experiment package absorbed sunlight rather than reflected it. But nobody knows for sure. LEAM operated only briefly before the Apollo program ended.

Then there are the puzzling rays seen by the Apollo astronauts. Because the specks of dust bouncing around on the moon would be too small to see with the naked eye, explorers on the surface wouldn't likely notice them. But astronauts on the night side around sunrise might see the moving dust causing the sunlight to scatter, looking like "a weird, shifting glow extending along the horizon, almost like a dancing curtain of light," according to Stubbs. And at certain times during the lunar cycle, when the moon passes through an active part of Earth's magnetosphere, Stubbs speculates that "dust would start flying at high velocities"—not at densities that could be seen from Earth, but perhaps in large enough amounts to get into unprotected machinery on the moon.

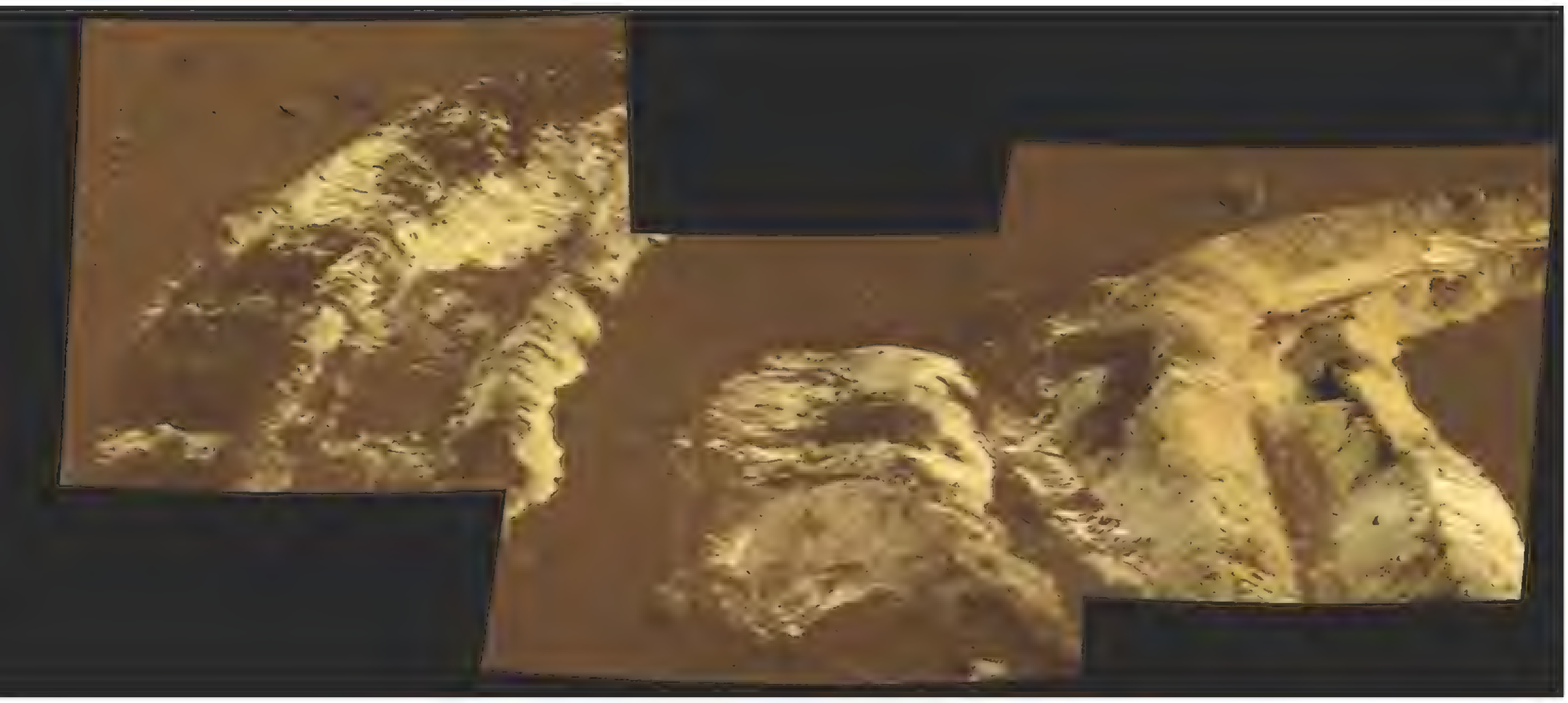
LAST YEAR, IN A 77-PAGE report listing 20 risks that required further study before we should commit to a human Mars expedition, NASA's Mars Exploration Program Analysis Group ranked dust number one. The report urged study of its mechanical properties, corrosiveness, grittiness, and effect on electrical systems. Most scientists think the only way to answer the questions definitively is by returning samples of Martian soil and rock to Earth well before launching any astronauts.


COURTESY COLORADO SCHOOL OF MINES

Many also believe a lunar sample return will be necessary. True, the Apollo astronauts brought back some 800 pounds of lunar rocks from six landing sites. But the dust played a dirty trick: The gritty particles deteriorated the knife-edge indium seals of the bottles that were intended to isolate the rocks in a lunar-like vacuum. Air has slowly leaked in over the past 35 years. "Every sample brought back from the moon has been contaminated by Earth's air and humidity," Olhoeft says. The dust has acquired a patina of rust, and, as a result of bonding with terrestrial water and oxygen

From its perch on a Martian hill, the Spirit rover watched towering dust devils (below, top center) swirl across the landscape. Below right: Dark dust-devil tracks photographed from Mars orbit show how common the storms are.


NASA/JPL (2)



NASA/JPL

Looking to the future, Colorado School of Mines researcher Mike Duke (opposite) and colleagues are designing excavators for lunar dirt. Wheeled vehicles on the moon and Mars sometimes churn up soil; material dug up by the Spirit rover earlier this year (left) gave scientists a peek at what lies underground.

molecules, its chemical reactivity is long gone. The chemical and electrostatic properties of the soil no longer match what future astronauts will encounter on the moon.

To better understand lunar dust, Olhoeft is trying to undo the damage. During the Apollo program six steel vacuum chambers were built, each 10 feet long, that could be pumped down to 10 to 12 torr—one- trillionth the atmospheric pressure of sea level on Earth—to duplicate the vacuum on the moon. After the Apollo program shut down, five of the giant tanks were scrapped. The remaining chamber, recently refurbished, is in Olhoeft's laboratory at the Colorado School of Mines. He plans to insert a sample of real lunar dust, pump the pressure down to lunar vacuum, cycle the chamber's temperature to duplicate the harsh lunar day and night, and bombard the contents with radiation and electrons to try to resuscitate some of its original properties.

At NASA's Marshall Space Flight Center in Huntsville, Alabama, in a smaller basketball-size vacuum chamber located inside the Dusty Plasma Laboratory, researcher Mian Abbas is running a positively Zen-like experiment. Each morning, he enters the lab and sits down to examine a single speck of lunar dust. For as long as 10 or 12 days at a stretch, he shines an ultraviolet laser onto the particle and painstakingly controls the strength of electric fields until the speck levitates. "Experiments on single grains are helping us understand how lunar dust on the moon can be given an electric charge and lofted to high altitudes," Abbas explains.

Olhoeft, Stubbs, and others are also mining original Apollo data, such as that from LEAM, in the hope that the unread tapes might yield information useful in designing lunar spacesuits and equipment. It's easier said than done: Many original computer tapes from Apollo experiments, including ones that were never analyzed, can no longer be read. Not only are some of the data formats obsolete, many of the tapes have degraded due to less-than-optimum storage. Some of the data may be permanently lost. So the dust researchers do what they can. They pore over frame after frame of footage taken by the Apollo astronauts, measuring the trajectory of dust particles kicked up by boots and rover wheels, hoping to better understand the physics. Others, like Bruce Damer of Digital Space in Santa Cruz, California, are building computer models of the dust so that design engineers can test-drive hypothetical digging machines and see what gets clogged.

While these scientists study the dust itself, engineers are coming up with prototype systems for combating it. At the Kennedy Space Center in Cape Canaveral, Florida, Carlos Calle and colleagues in the Electrostatics and Surface Physics Laboratory have demonstrated a device they think can be embedded in spacesuit fabrics to create oscillating electric fields. The rapid shifting of the fields would cause dust particles to hop from electrode to electrode until they get thrown off the suit altogether. An even more imaginative dust-busting concept comes from Lawrence Taylor, a planetary scientist at the University of Tennessee at Knoxville, who describes himself as "one of those weird people who

BECAUSE THE SPECKS OF DUST BOUNCING AROUND ON THE MOON WOULD BE TOO SMALL TO SEE WITH THE NAKED EYE, EXPLORERS ON THE SURFACE WOULDN'T LIKELY NOTICE THEM. BUT THE MOVING DUST MIGHT CAUSE SUNLIGHT TO SCATTER.

like to stick things in kitchen microwave ovens to see what happens." When he tried it with a small pile of lunar soil, he found that it melted "lickety split"—within 30 seconds—at only 250 watts of power. The nanophase iron in the dirt concentrated the microwave energy to sinter, or fuse, the loose soil into large clumps. Taylor's experiment has inspired him to propose machinery for turning bothersome lunar dust into useful solids: rocket landing pads, bricks for habitats, radiation shielding, even roads and radio antenna dishes.

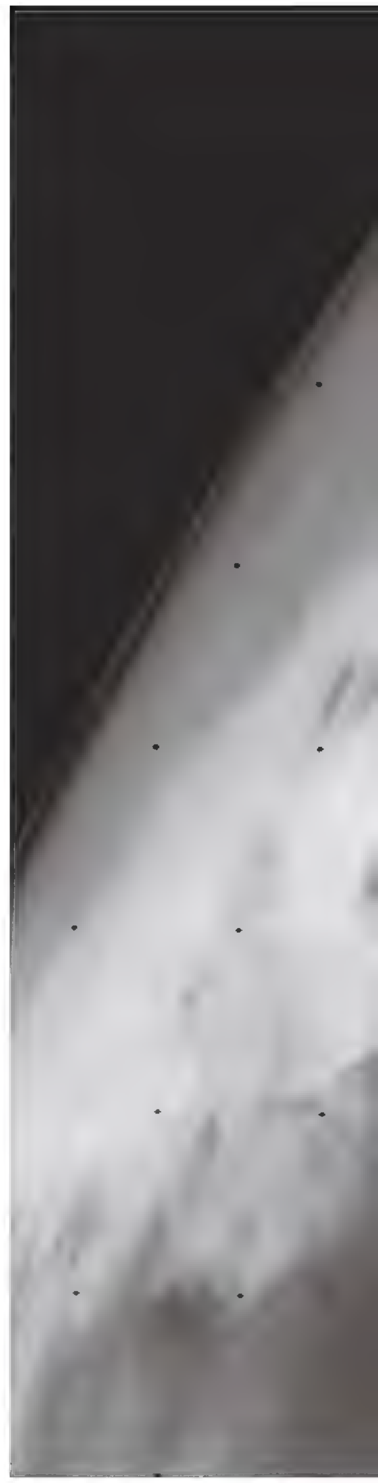
That's the other thing about dust: It isn't always bad. On Mars, dust might actually help clean up its own mess. The solar panels on the twin rovers currently on Mars were expected to have been coated long ago with dust that would degrade their power output and bring the mission to a halt. More than once, though, tornado-like dust devils have scoured the panels clean and given the rovers new life.

DURING MARTIAN SUMMER, THE PLANET'S DUST DEVILS COME ALIVE. THESE ARE NO LITTLE ARIZONA DESERT WHIRLWINDS, A FEW YARDS ACROSS. MARTIAN DUST DEVILS ARE MONSTER COLUMNS REACHING MILES INTO THE SKY.

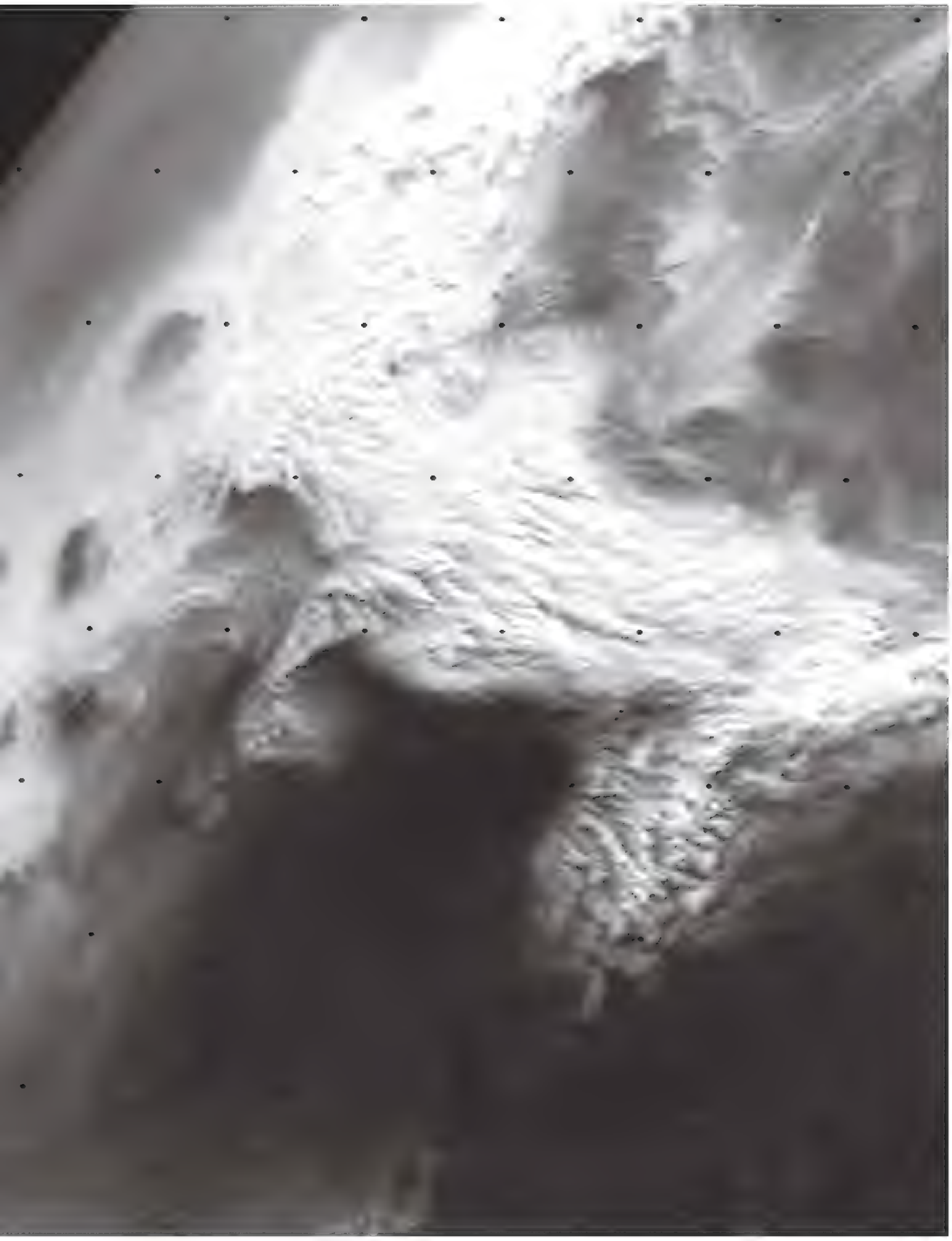
But that's the rare bit of good news. Dust storms on Mars will be a serious, continual worry. During Martian summer, daytime highs peak at 68 degrees Fahrenheit, and on these balmy afternoons the planet's dust devils come alive. These are no little Arizona desert whirlwinds, a few yards across, that pass by in seconds. Martian dust devils are monster columns reaching miles into the sky and nearly half a mile across, 10 times larger than any tornado on Earth. When they pass by, the reddish sand and dust whips around faster than 70 mph, dropping the local visibility to zero for minutes at a time. And they're everywhere. The Mars rover cameras have filmed them in action, and orbiting spacecraft have spotted their dark tracks all over the planet. "If you were standing next to the Spirit rover midday during Martian summer, you'd see half a dozen [dust devils] at any instant," says Mark Lemmon, a Mars atmosphere specialist at Texas A & M University in College Station.

The sand in the lower part of a Martian dust devil would be a major hazard. Because the atmospheric pressure on Mars is only one percent of that at sea level on Earth, astronauts won't feel much wind. But their spacesuits and faceplates would be pinged by high-speed material that would collect in every fold and crevice. Worse, the swirling dust and sand may be electrically charged, to the point of "possibly inducing arcing to a spacesuit or vehicle, and creating electromagnetic interference," according to William Farrell, one of Stubbs' colleagues at NASA's Goddard center.

Farrell has chased dust devils across Arizona deserts and measured their electrical currents. Like levitat-

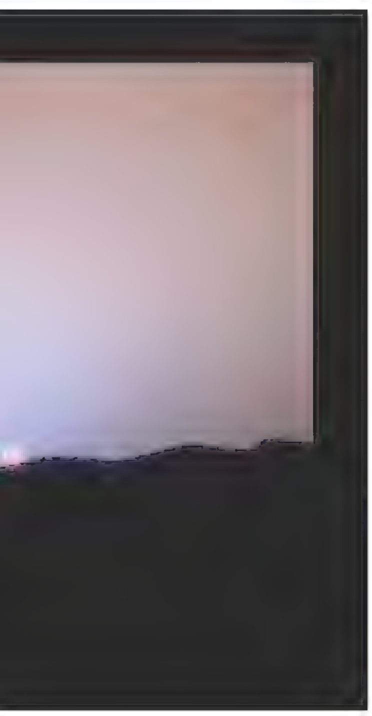


Martian sunset, as seen by the Mars Pathfinder in 1997. Dust particles in the thin atmosphere produce unexpected colors on this alien world. By day the sky is pink, but when sunlight passes through denser dust close to the horizon, the sky turns blue.



NASA/JPL (2)

The dark shadow of a dust storm begins to spread across Mars.



ing lunar dust, the grains of sand and dust become charged as a result of constantly banging into one another. On Mars as well as on Earth, the dust, which can blow in from anywhere, may be quite different from the local sand. When unlike materials rub together (like party balloon and shirt sleeve), one material gives up some of its electrons to the other in what's known as triboelectric charging ("tribo" means "rubbing"). The smaller dust particles tend to take on a negative charge, having robbed electrons from the larger sand grains.

Triboelectric charging is known to occur on Mars. It came to the attention of NASA engineers building the Sojourner rover for the Mars Pathfinder even before the spacecraft left Earth. When the engineers ran the wheels for a prototype Sojourner over simulated Martian dust in a simulated Martian atmosphere, the model built up a charge of hundreds of volts. That discovery inspired the scientists to add ultrathin half-inch-long tungsten needles at the base of the rover's radio antennas, to drain any excess charge into the thin Martian air.

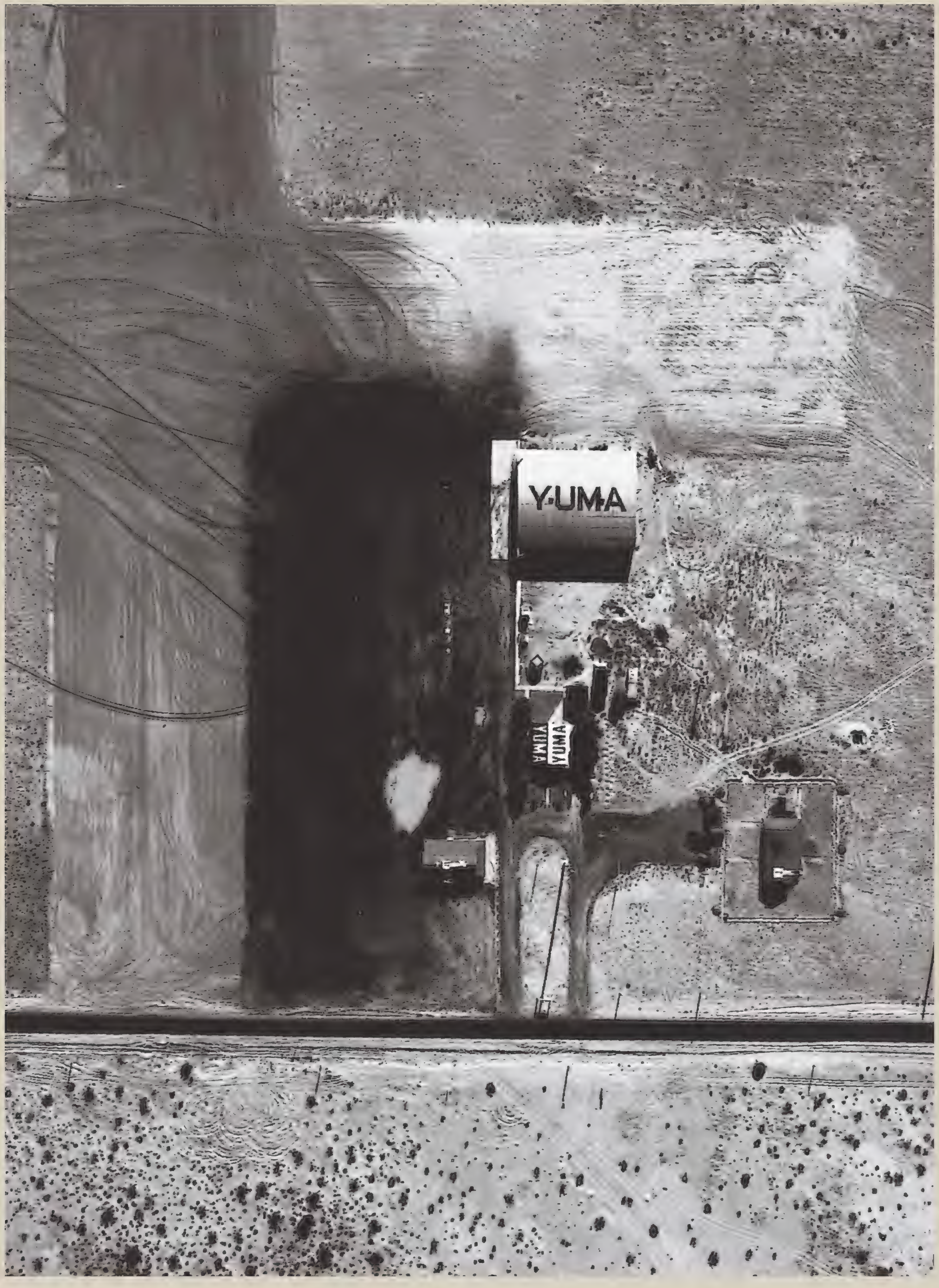
NASA VIA ANDREW CHAIKIN

John Young uses a brush to clean lunar dust off Charlie Duke. (Image from a video.)

Dust devils could even lead to lightning on Mars. All dust devils are powered by a rising central column of hot air, which carries the negatively charged dust upward and leaves the heavier, positively charged sand swirling near the base. The charges become separated, and the separation creates an electric field. In terrestrial dust devils, Farrell has measured electric fields of up to 20,000 volts per meter—peanuts compared to the fields in thunderstorms, where lightning doesn't flash until the fields become 100 times stronger, enough to break apart air molecules. But 20,000 volts per meter "is very close to the breakdown of the thin Martian atmosphere," Farrell points out. And because Martian dust devils are so tall, their stored electrical energy can be greater, possibly strong enough to unleash lightning.

Even if lightning doesn't occur on Mars, the presence of an astronaut or rover might induce local arcing. "You'd have to watch out for corners, where electric fields can get very strong," Farrell muses. "You might want to make a vehicle or habitat rounded." And though dust devils can clean off solar panels, astronauts may still find charged dust clinging electrostatically to spacesuits, vehicles, and habitats.

None of these concerns is especially troubling to Apollo 17 astronaut Schmitt. He agrees that dust will be a nuisance for future lunar explorers. But he also expects that engineers will come up with practical solutions like an airlock—which is already being considered for the next-generation lander—that would let astronauts stow their dirty spacesuits before re-entering their living quarters after a moonwalk. "For scientific reasons, the dust is intriguing," Schmitt says. "It's a number-one engineering design problem for long-term habitation and settlement [of the moon]. But you protect yourself with a layered defense. The dust is *not* a problem that should scare us out of going back."



ALL PHOTOGRAPHS: NATIONAL ARCHIVES

Show Me the Way to GO HOME

Long before the Global Positioning System, pilots got from town to town by reading rooftops.

by Roger A. Mola

FOR SIX YEARS, demonstration and race pilot Blanche Noyes had ridden herd on a government program that called for navigation markers to be placed on building rooftops to help pilots find their way from one town to another. By 1941, some 13,000 marks had been painted on barns, hangars, skyscrapers, oil tanks, and train stations. Now, in January 1942, on the heels of the attack on Pearl Harbor, the Civil Aeronautics Administration, goaded by the War Department, directed that all air markers near both coasts be obliterated.

"The number of military ships which have been forced to land due to running out of gasoline...has been appalling," Noyes later wrote to her bosses, blaming the loss of air markers. The CAA chief of airways countered: "The Army feels that the value of markers to the enemy overshadows the need by our pilots; therefore the air marking project will remain suspended for the duration of the emergency."

Before radio navigation was widely available to pilots of small aircraft, they got around by flying by landmarks. In unfamiliar terrain, however, it was easy to get lost, so in 1926 the government set out to promote air marking, painting the name of a local airport on a nearby building's roof with an arrow pointing in the airport's direction, or simply the name of the town with an arrow indicating north. Though federal aviation agencies regulated every aspect from letter size (10 to 30 feet tall) to paint (Chrome Yellow Number 4 on a black background) to distance between markers (one every 15 miles was the goal), they never lifted a brush. Labor came from the Works Progress Administration, the Civil Air Patrol, the Civilian Conservation Corps, civic volunteers, scouting organizations, and the Ninety-Nines organization of women pilots. Along with the safety benefits of guided navigation, air marking was variously touted as a job program, a scout merit badge, a commercial welcome mat, and a boon to women in aviation.

The roof of the building chosen to host El Paso's air marker required some ingenuity in siting the letters.

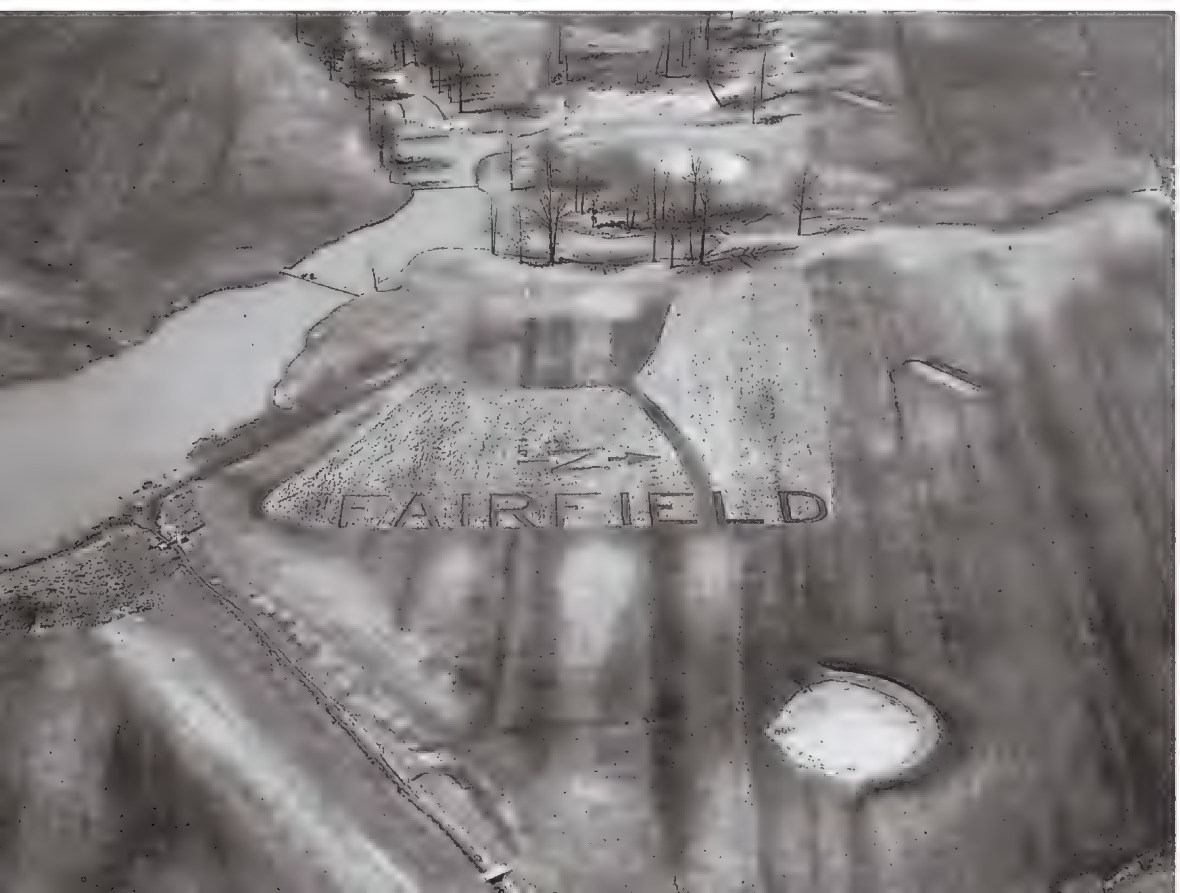
Phoebe F. Omlie, an official of the National Advisory Committee for Aeronautics, hand-picked prominent pilots Nancy Harkness, Helen MacCloskey, and Louise Thaden as field reps for the program. A year later, Noyes became the fourth pilot hired to charm public works officials into painting the town.

"Why do they choose girls to do this work?" asked Helen MacCloskey in *A Million Dollars Worth of Safety In Five Gallons of Paint,* an article that was included in a promotional kit sent to editors throughout the country. "I expect because there are still few enough women pilots in the country, [they think] we could do a better job of selling the interests of private flying."

Louise Thaden wrote in *Southwestern Aviation,* "Air route markers are more important than the highway markers, because a pilot can't stop at every crossroads and shout to ask 'which way to where,' which

In a pilot's-eye view, Yuma Flying Field in Arizona read loud and clear. But could pilots confuse it with Yuma, Colorado?

Steelton, Pennsylvania, chose a gas storage tank (doubling as a giant sun dial) to direct pilots to Harrisburg and an air depot (above). Air Marking chief Blanche Noyes (at left, in pearls) and local and national officials, including Civil Air Patrol deputy commander Colonel Robert L. Scott Jr. (far left, front row), posed for the painting of the Albany, Georgia air marker in 1947. Fairfield, Illinois, made good use of a fair field (below).



oftentimes leads to very embarrassing predicaments. Cross-country travel by automobile wasn't any great shakes until roads were improved and directional signs erected."

Assistant Secretary of Commerce J.M. Johnson helped promote the program by pointing out that a blank roof was bad business. "The roof as airmarked constitutes one of the most effective as well as inexpensive advertisements, directed to an excellent class of people," he wrote in the kit. "The town may appear as a good place for a vacation, a home or a business. The air marker puts the town on the map." Commerce meant it literally: A town could not be listed on the department's aeronautical charts until it accepted an air mark.

In 1937, Noyes considered the fire watch towers in national forest lands, and asked the Civilian Conservation Corps, national parks, and the U.S. Indian Forest Service to air-mark their galvanized roofs. Her colleague Henry Knight pitched in. "In my sales talk I emphasized the danger in forced landings as a major fire hazard for our national forests," he wrote to A.B. McMullen, chief of the airport section at the Bureau of Air Commerce. "I doubtlessly exaggerated, but nevertheless, it is a possible hazard." Marks were also plowed into fields, spread in brick, cinder, or gravel, and built with river stones. Pilots already followed railroad lines, so air marks were wedged within ties.

The CAA even called in the Boy Scouts. An issue of *Scouting* featured Road Signs of the Air:

Markers keep you safe from harm,
Tell of towns and ports nearby,
Tell the mileage you must fly,
Give your longitude and latitude,
Give you everything but altitude.

Late in 1938, a letter arrived at the CAA from the National Broadcast Company at Sunset and Vine, Hollywood, offering the service of a pair of popular entertainers. "Amos 'n' Andy are veteran flyers and Andy (Charles Correll) not only owns his own plane but is a licensed radio operator," wrote Harold Bock, the press manager for the comedy duo, who performed in a daily radio show. Bock suggested using the well-known voices of Correll and his fellow comedian, Freeman Gosden (Amos), in radio pleas to paint every prominent roof—as long as the government paid for an office, clerk-typists, stationery, and postage. That way, Bock wrote, "Communications would be accepted as official, rather than as a publicity stunt." The campaign, "Let the Air Know You're There," would include broadcasts by Hollywood pilots and coverage by newsreels and radio commentator Ed Sullivan. Noyes' interest was piqued, but shortly thereafter, in January 1939, Correll's family had to attend to a medical emergency, and he was unable to meet her.

Readable from as high as 10,000 feet, air marks

were invisible at indirect angles or if the lighting was not optimum. And markers of all sorts eventually faded, flooded, blew away, burned, or crumbled.

Then came December 7, 1941. On December 22, the chief of CAA airways engineering, C.M. Lample, wrote to Allan Perkinson, Virginia's director of aeronautics and a friend of Noyes. "We requested the War Department to state whether they consider the obliteration of any existing markers as necessary in connection with the national emergency," Lample reported. "We have requested the same comments from the Office of Civilian Defense. Neither organization has replied. In the absence of these replies, it is our opinion that the air marking program should be continued."

On January 17, the War Department finally responded: Obliterate all air markers within 150 miles of the Atlantic and Pacific coasts. In the area between, no new markers were to be constructed. Secretary of War Henry Stimson nixed Buffalo, Detroit, Duluth, and Sault Ste. Marie air marks. But Stimson allowed markers to be reinstalled within 50 miles of air fields conducting flight training.

During the war, Noyes limited her role to inspection. She noted in the *Christian Science Monitor* in 1943, "Once in a while I get a little jittery wondering if some particularly zealous airplane spotter might mistake me for an enemy ship and shoot me down and ask questions later, for of course I'm constantly flying over restricted areas."

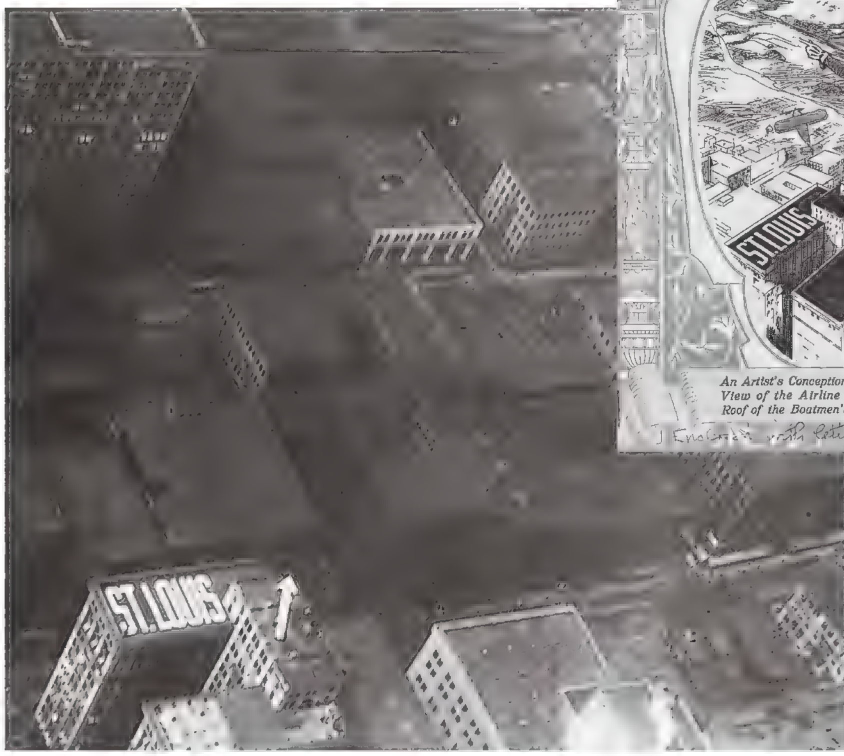
In 1944, the CAA had decided to add longitude and latitude to the air marks. The Administrator cited the existence of six towns in Ohio named Summit to show that a name alone was insufficient. The following year, the air marking program was resumed, but only 66 markers were installed by year's end. Thomas Bourne, assistant administrator for federal airways at the CAA, had a bright idea.

"We have had a great number of requests for illuminated city identification markers," Bourne noted in a letter to a Washington, D.C. commissioner. "It is only fitting that the capital of the United States should be the first." Bourne wanted to place amber bulbs turned skywards in 229 street lamps in Washington. "This method would be of great value to the pilot who is lost, as well as to the air traveller who is interested in identifying the various cities over which he passes and within sight of." But the CAA soon tired of working the D.C. bureaucracy and the idea faded.

After the war, Noyes was put in charge of the air marking division of the renamed Civil Aeronautics Authority. An ardent supporter, she flew around the country seeking financial support from local chambers of commerce when federal funding ran dry.

Virginia's Allan Perkinson forwarded a letter and news clip to Noyes from her friend Patricia Davis Arnold, a Ninety-Nine who had circled at length

St. Louis himself herds aircraft toward the airport (inset) from Boatmen's Bank, where the air marker was set on the roof.



over Damascus, Virginia, until seeing an air mark. Noyes sent copies to every state aviation director, noting in the margin, "I wish all girls would follow her example and send me reports of air marking help." Perkinson told the media that it was the pilot who was at fault; had she the courtesy to become lost in the right place, she would have seen his air mark sooner. "There are no doubt many towns which are airmarked and yet the Chambers of Commerce and municipal officials do not know it," he added.

Noyes continued giving speeches entitled "Mark the Skyways Like the Highways," but increasingly her presentations were for club chapter meetings or at coffee shops in the Washington suburbs. By this time, navigation charts and radio had worked their way into most cockpits.

Today, the Ninety-Nines paint compass roses on runways but no rooftop signs. They sell penny-a-pound passenger flights to pay for paint and supplies, and local airport businesses have pitched in funds.

Sophia Payton, a Ninety-Nine in Clearwater, Florida, painted air marks on roofs in 1946 in Indiana and Ohio. "That was a big project; all the girls up on rooftops," she recalls. "We'd pull our whole chapter together, 10 or 12 of the girls, pull out our brushes, and follow the federal criteria. It was a lot of fun, a lot of work; it was...productive."

Payton keeps a letter of thanks sent to the Postmaster of Shirley, Indiana, in 1956. Colonel C.E. Fulton of the U.S. Air Force was heading toward St. Louis when the weather deteriorated. He emerged from clouds to read the 10-foot SHIRLEY atop a canning company.

KEEP WATCH

MEET THE SATELLITES BRINGING DATA TO

ING THE ICE

THE DISCUSSION OF GLOBAL WARMING.

BY BEN IANNOTTA

IN EARLY MAY, WHEN MOST PEOPLE in the United States enjoy the warm days of spring, veteran NASA glaciologist Jay Zwally instead heads north to the ice-bound edge of western Greenland.

It takes two aircraft, an LC-130 transport and a de Havilland Twin Otter, to get him to a collection of tents pitched on a wooden platform, known by glaciologists as the Swiss Camp. The name is a remnant of its origins as a research site operated by a Swiss university, now used by NASA and others to measure the effects of climate change.

Just south of the camp lies the Jakobshavn Glacier, a thick slab of ice that is gradually sliding downhill toward the Greenland coast. At the water's edge it becomes the Jakobshavn Isbrae, a tongue of ice spilling into a natural inlet. The surface of the glacier melts in the summer, and Zwally needs to prepare his Global Positioning System sensors in the ice to measure how the surface water affects the glacier's velocity.

When Zwally is not on the glacier, he's in Maryland running the science side of a $283 million NASA satellite project that is watching it. Whether deploying equipment on the ice or into orbit, he is seeking data to answer some of the thorniest questions in the debate over global climate change: How quickly will Earth's ice melt as the planet continues its expected warming trend, and what will the extra water do to sea levels?

In the community of glaciologists, Zwally's training as a mechanical engineer and physicist is unusual. As a young engineer in the 1960s, he built part of a solar wind detector that flew aboard NASA's Explorer 34 scientific satellite. He then earned a Ph.D. in physics from the University of Maryland but couldn't find a job in that field. "I got this wonderful opportunity to go to the National Science Foundation and I got into glaciology, polar research," Zwally says. In 1974, he moved to NASA, and now works at the Goddard Space Flight Center in Greenbelt, Maryland.

In the mid-1980s, Zwally first conceived of a satellite that could measure Earth's ice by bouncing infrared laser pulses off Earth's ice sheets. In January 2003, NASA launched the Ice Cloud and Land Elevation Satellite, or ICESat, with Zwally serving as project scientist. Forty times a second, ICESat fires its laser, catches the reflections with its telescope, and calculates the height of the ice based on how long it takes the signals to return.

ICESat's altimeter data will enable scientists to calculate the volume of the ice still present in Earth's glaciers. By comparing the measurements taken over the life of the satellite, scientists will figure out whether Earth's glaciers overall are losing or gaining ice, and if so how much.

ICESat is one of two satellite systems NASA is counting on to make the first truly quantitative, three-dimensional measurements of the planet's ice cover. The second system, the Gravity Recovery and Climate Experiment, or GRACE, consists of twin satellites that can sense the shrinking of ice sheets by measuring the diminishment of their gravity tug. GRACE was launched in March, 2002.

Armed with these satellite measurements, glaciologists are taking the first steps toward predicting how much ice will disappear from Earth in the coming decades—the critical figures of "how much and when," Zwally calls them.

At the moment, water that might otherwise flood coastal cities and towns around the world remains locked away as ice, much of it in Antarctica and Greenland. "The glaciers have in them on the order of 70 meters—200 feet—of potential sea level rise," says Bruce Wielicki, a senior scientist at NASA's Langley Research Center in Hampton, Virginia. "No one is talking about us getting all 200 feet in the next 100 years, but the point is, even if you only got five of that 200 feet, where I live, our average elevation is about three feet. So the costs of dealing with sea level change are one of the huge potential issues."

Initial data from GRACE has already sparked debates and some concern. "We're seeing very quick responses to changes in temperature, responses that people used to think would take hundreds or thousands of years," says Zwally's boss, glaciologist Waleed Abdalati, head of the Cryospheric Sciences Branch at the Goddard Space Flight Center. "It's not a 'run for the hills' kind of story, but it's 'Wow, this is serious.' Things seem to be stirring in a way that is going to contribute to [an increase in] sea level."

But there is no agreement among scientists on how quickly the sea level will rise, how quickly the global climate will heat up, or even how warm Earth might get. According to a panel of scientists who looked into the question for the Bush administration in 2001, the temperature could rise an average of 2.5 to 10.4 degrees Fahrenheit in the next 90 years.

What is certain, even among scientists who have criticized their colleagues for over-hyping global warming, is that at least some of Earth's warming is due to a buildup of carbon dioxide from the burning of fossil fuels. These gases trap heat from the sun, resulting in the greenhouse effect. The main disagreement is over the urgency of the problem.

"This issue is not going to come and kill us all, despite the apocalyptic renditions you see in newspapers," says University of Virginia climatologist Pat Michaels, whose book *Meltdown* criticizes the methods used by most climate scientists. Michaels calculates the pace of human-caused warming to be slow enough for correction: "We have time to invest in future [energy] technologies."

More information is needed to gauge the seriousness of the problem. If ICESat corroborates the GRACE findings, Earth's coastlines could look dramatically different within 100 years.

GRACE is the first satellite system of its kind. It consists of two satellites that

The edge of western Greenland, where the Jakobshavn Glacier meets Baffin Bay, is a nursery for new icebergs. Researchers are studying the effect of this movement on the levels of the planet's oceans.

KONRAD STEFFEN

follow the same orbit about 120 miles apart, says Mike Watkins, the GRACE project scientist at NASA's Jet Propulsion Laboratory in Pasadena, California. "This is not like the 13th mission to make the same measurement a little bit better," Watkins says. "It's really a revolutionary thing."

When the lead GRACE satellite reaches a point in its orbital path above an area of increased mass, such as a mountain or ice sheet, the corresponding increased gravity tug slows it down and changes ever so slightly the distance between it and its twin. Microwave signals that are continuously passed between the two satellites now arrive at slightly different points along their wavelengths than they did before the slight disruption. GRACE's electronics detect the change, and software measures the change in distance between the satellites to an accuracy of one micron, or a millionth of a meter.

A team of researchers at the University of Texas' Center for Space Research in Austin converts that data into monthly maps that are color-coded to show changes in the distribution of Earth's mass—primarily the movement of water. Other researchers use the data to explore the rate of the planet's ice loss. Isabella Velicogna and John Wahr, satellite researchers at the University of Colorado in Boulder, wrote what is perhaps the most stunning GRACE-based report. The two examined the data and reported in the March 2, 2006 issue of *Science* that Antarctica is losing 36 cubic miles of ice a year. That's enough to fill Lake Erie in three years.

The job facing Velicogna and Wahr was not quite as simple as placing the entire Antarctic ice sheet on the equivalent of a bathroom scale. Earth's crust is still rising in some places and subsiding in others in reaction to the weight lifted by the melting of the glaciers at the end of the last ice age, more than 10,000 years ago. The scientists had to factor out the post-glacial rebound. "We use some models to remove this signal, and then what's left is the mass change of the ice," Velicogna explains.

Zwally doesn't doubt that Antarctica's ice cover is shrinking, and the effect over the centuries could be devastating, but he thinks Velicogna and Wahr have the scale wrong. "Too big a number for Antarctica," he says tersely over the phone, while preparing to leave for Greenland. He later adds that a true accounting of ice being lost will be calibrated by ICESat, aiding scientists' calculations of the resultant rise in sea levels.

The strength of GRACE is that it accurately measures mass, providing hard numbers for the amount of ice lost, but only on geographic scales large enough to produce a gravity tug that can be sensed.

ICESat works nothing like GRACE, which is why glaciologists are curious to see whether the findings from the two projects corroborate each other.

When Zwally started advocating for ICESat among his colleagues, he knew the potential of using altimeters to measure ice, but also saw the limits of flying them on airplanes, which was the common method. Only a satellite orbiting from pole to pole could provide the coverage necessary to monitor content across an entire continent or subcontinent. Radar satellites were on the horizon, but Zwally knew those readings would be much less precise because radar wavelengths are longer than those of laser light. "Satellite radar can't get all the way to the edges of ice," Zwally says. "There's penetration too. The radar penetrates some distance into the snow. And that has some variability depending on the properties of the snow. The laser measures directly to the surface."

ICESat measures the height of Earth's surface every 660 feet, so it can examine relatively small features. "What ICESat can do is provide very high resolution on a particular track: What's happening on this glacier?" says Jim Abshire, a soft-spoken native of Tennessee whose job is to ensure the accuracy of ICESat's laser system.

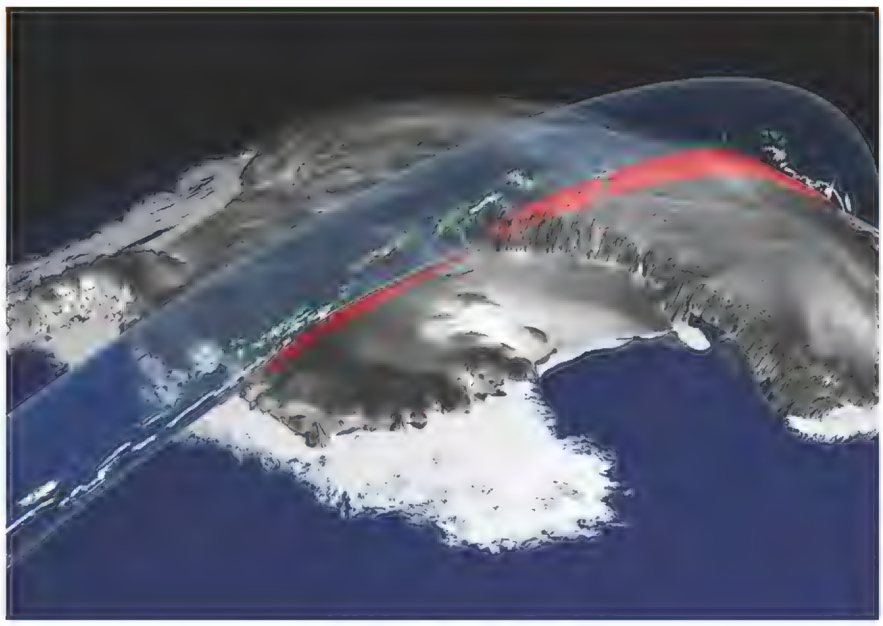
NASA had planned to run ICESat's three

NASA

ICESat

Date Launched: January 2003
Weight: 2,100 lbs.
Predicted Life: 3 years
Project Cost: $283 million

Details: A laser altimeter system measures ice sheet elevation and sea ice thickness.



NASA GODDARD SFC

On its first day of operation, February 20, 2003, ICESat returned this data on ice sheet elevation and cloud coverage.

lasers in sequence until they burned out—ideally after at least five years of continuous measurements. But ICESat managers were shocked when one of the lasers fizzled after just 36 days. NASA rushed to assemble a review panel headed by veteran NASA engineer Bob Kichak, an expert in spacecraft power systems, to determine what went wrong and whether anything could be done to save the remaining two lasers.

Inside each ICESat laser, dozens of half-inch-long light-emitting diodes project light onto a metallic crystal. The electrons in the crystal become so energized that they release pulses of laser light. The diodes are linked to a power supply by numerous hair-like gold wires. NASA officials disassembled a spare unit purchased from the manufacturer, Spectra Laser Diodes of San Jose, California, and examined the diodes under high magnification. Kichak's board concluded that "excessive" amounts of metallic indium solder, used to hold the diode assembly together, had most likely contacted the gold wires and eroded them, causing a catastrophic loss of power. The most likely cause for the presence of the extra solder was a manufacturing error.

Based on Kichak's recommendations, NASA ordered a complete overhaul of ICESat's operating plan. To conserve the lasers, operators can turn them on only three times a year for 33-day-long "campaigns." ICESat's cooling system would slow any chemical erosion. Engineers eventually decided to run the lasers at a temperature of 14 degrees Fahrenheit, says Zwally.

The decision dimmed the laser's visible, green light, so ICESat's secondary measurements of aerosols and clouds can be gathered only at night. The ice and land elevation readings aren't compromised because they require only the lasers' infrared channel, Zwally says.

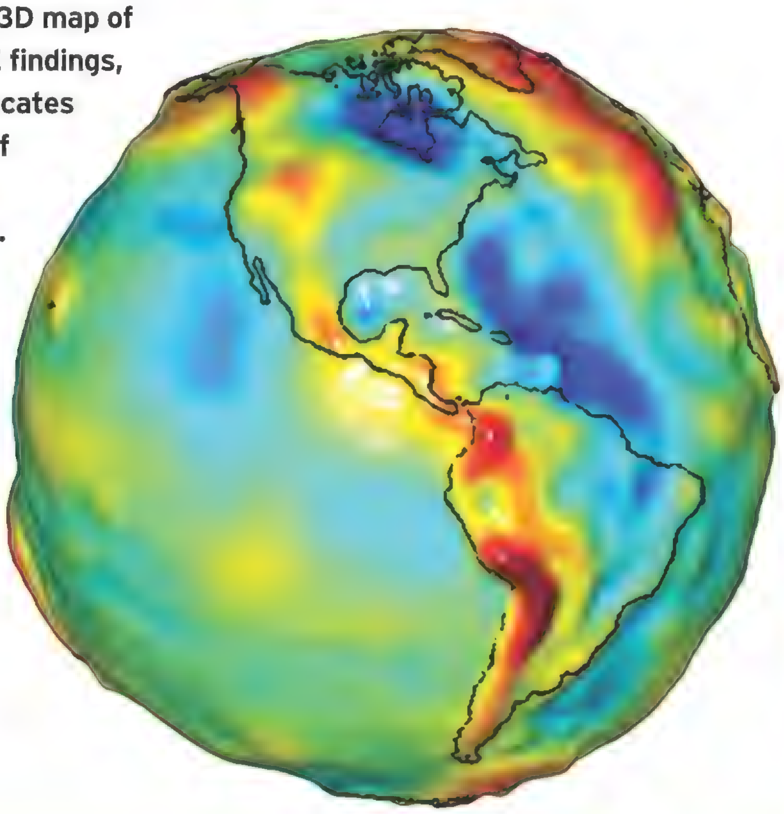
NASA officials breathed cautious sighs of relief as the second and third lasers were turned on and ICESat gathered data successfully. The second lasted about 100 days before officials decided to turn on the third.

Abshire says that even with initial drawbacks, the lasers have performed better than expected. Satellite-based instruments often have Achilles' heels, and in the case of ICESat, the weakness is a slight laser-pointing error as ICESat crosses in and out of Earth's shadow. To measure the effect, experts from the Scripps Institution of Oceanography in La Jolla, California, drove SUVs over a salt flat in the mountains of Bolivia using GPS receivers to survey the terrain. ICESat passes within range of this salt flat every two weeks, and during those passes, controllers program the satellite to turn sideways so that its laser bounces off the salt flat. By comparing those readings to the ones from the GPS receivers, scientists know that ICESat is operating with an absolute accuracy as fine as seven centimeters (2.7 inches), better than the original target of 10 centimeters, Abshire says. When mathematical models are applied to subtract the known aiming errors, the instrument has proven to make repeatable measurements with a margin of error as low as three centimeters.

The new ICESat operating plan has made the job of steering and controlling the spacecraft more complicated for the staff and students at the University of Colorado's Laboratory for Atmospheric and Space Physics in Boulder. LASP officials had assumed they would settle in to a pattern of routine monitoring from the lab's cozy mission operations center. But during a teleconference in 2003, NASA managers outlined the new operating scenario to the LASP staff. "When we went to that telecon we went, 'Whoa! They're going to correct a manufacturing defect with an operational workaround,' which wasn't unheard of," says veteran satellite controller Jack Faber, an operations engineer who also teaches satellite control at the University of Colorado. "The bottom line was LASP is going to have to do a lot of work."

The satellite is steered not by rockets but

In this 3D map of GRACE findings, red indicates areas of strong gravity.

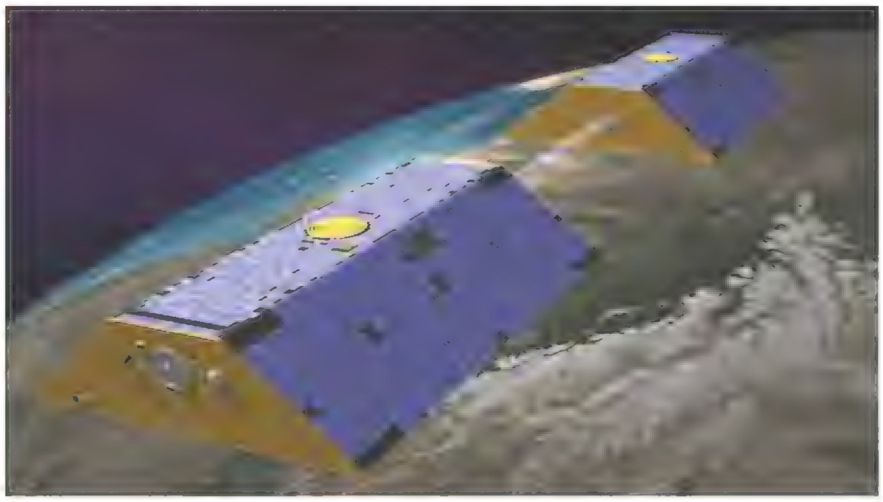


UNIV. OF TEXAS CENTER FOR SPACE RESEARCH

GRACE

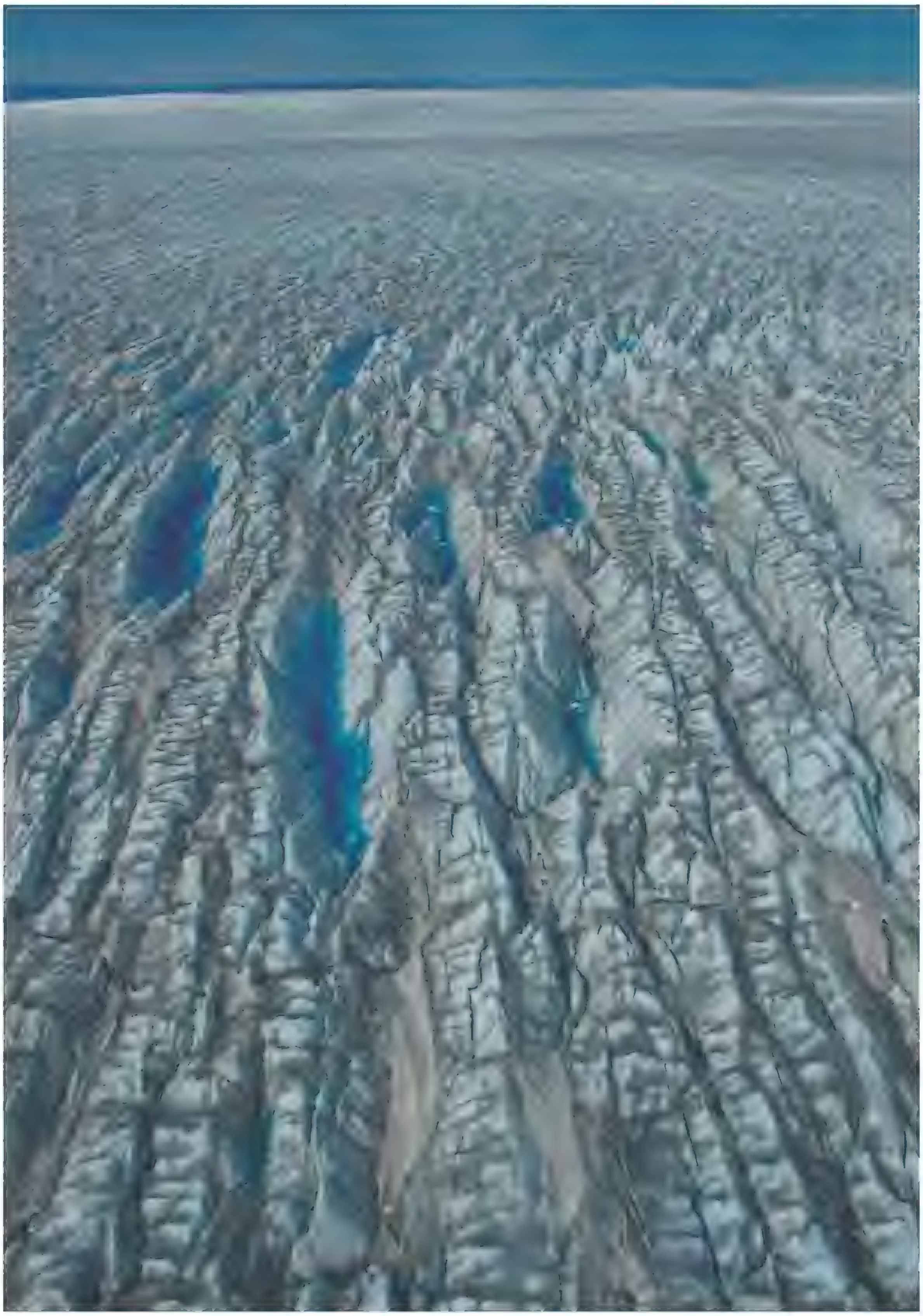
Date Launched: March 2002
Weight: 950 lbs. (each)
Predicted Life: 5 years
Project Cost: $127 million

Details: Twin satellites fly 120 miles apart, mapping gravity fields to chart the distribution of Earth's mass, including ice.



NASA

JAY ZWALLY



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NASA researchers unload supplies during a 2006 trip to Greenland (left). Meltwater forms lakes on top of Jakobshavn Glacier, but eventually trickles to the ground. There, the water helps lubricate the glacier's movement.

by electric-powered reaction wheels, which spin at differing rates to create a predictable torque that changes the direction in which the satellite points.

Since ICESat studies the changes in glaciers, volcanoes, and river basins that might be off its orbital track, LASP controllers must be ready to turn it to face targets of opportunity. Now that ICESat is run intermittently, the controllers have to work harder during the limited time. Controllers must upload aiming commands approximately once a week instead of once a month, as was the original plan.

ICESat's laser campaigns are intense affairs in which controllers closely monitor the temperature of the laser subsystems for signs of trouble. Each time the satellite comes into range of a ground station, controllers have about 12 minutes to send commands and download the all-important temperature readings.

On one sunny afternoon at LASP, ICESat has risen above the horizon north of Alaska and into range of the Svalbard ground station in the Norwegian Arctic.

Faber and Chris Bunch, a 22-year-old mechanical engineering student, are ready to make contact with the craft, and Bunch is twirling a pen nervously in one hand.

Faber's graying beard and jeans may look typically Boulder, but he's anything but casual about running the operations center. He once famously booted the LASP director out of the control center for being distracting during the critical moments after a satellite launch.

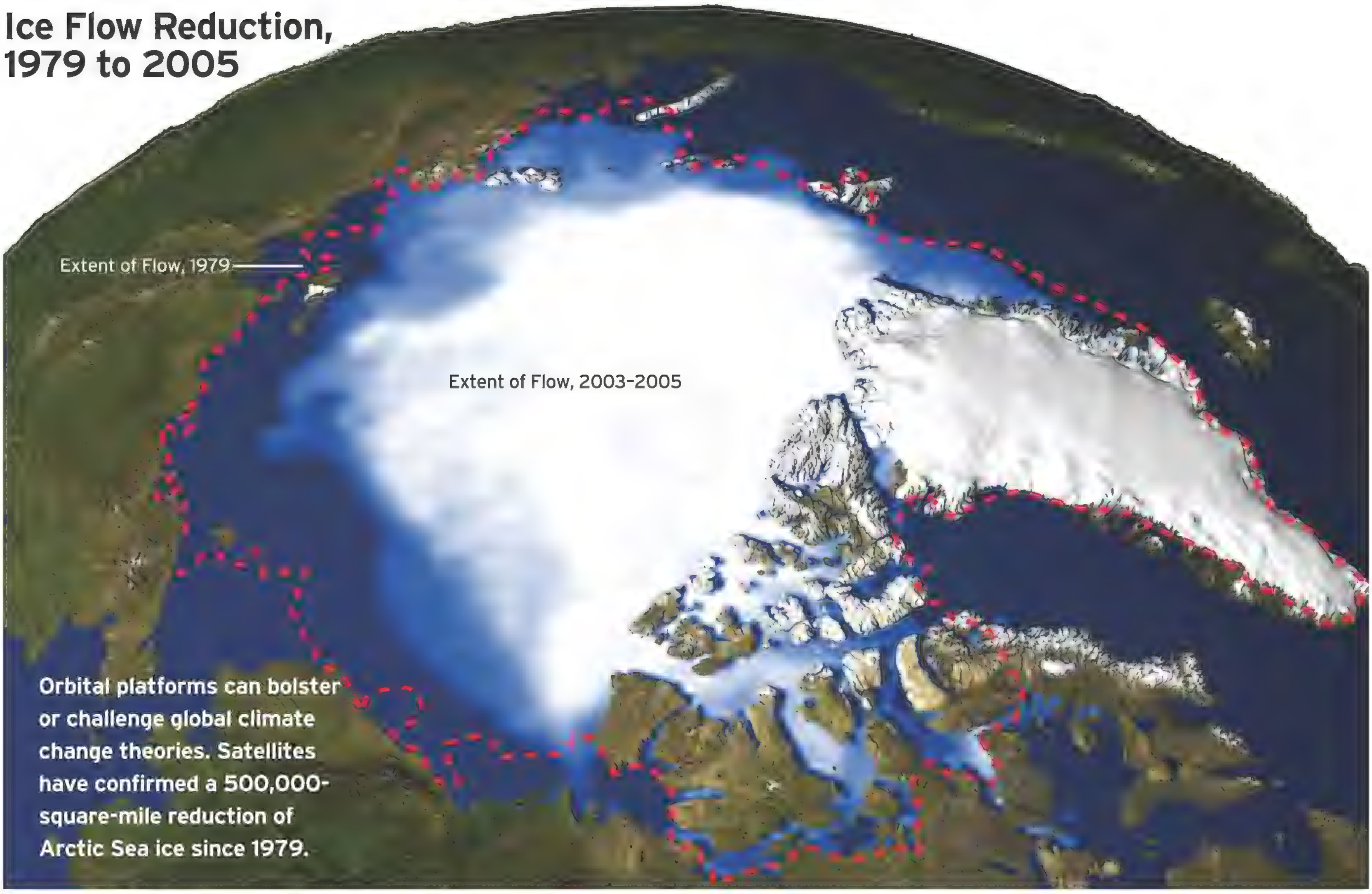
"Stand by for table 29?" Bunch asks, referring to software that will pave the way for ICESat to receive the latest set of operating commands.

"Okay for 29," replies Faber.

With the commands on their way, Faber quickly checks the status of the laser system. Among the streams of acronyms and numbers that fill his computer screen are eight circular "gumballs" summarizing the status of ICESat's critical systems.

All eyes are on the gumball labeled "Thermal." It has come up a happy green. If it were red, cell phones and pagers would have

Ice Flow Reduction, 1979 to 2005



Orbital platforms can bolster or challenge global climate change theories. Satellites have confirmed a 500,000-square-mile reduction of Arctic Sea ice since 1979.

NASA

sounded from Colorado to Maryland as engineers got to work figuring out how to cool ICESat's last laser before it burned out. Just to be safe, Faber checks more temperature readings. "Everything is fine," he says.

Engineers hope to squeeze another five or six campaigns out of Laser 3, ICESat's last fully functional laser. Despite the problems, Zwally counts the launch of ICESat in January 2003 as his biggest achievement at NASA. Still, he will be the first to say that scientists cannot rely on space-based sensors alone to answer questions about Earth's glaciers. Sometimes they need to get close.

At the Swiss Camp, Zwally ventures out by snowmobile to drill holes in the ice and insert poles equipped with GPS receivers. As the glacier moves, the GPS units will move with it, and Zwally will record its speed.

When Zwally started this GPS research in the mid-1990s, fellow glaciologists were surprised by his results. The Jakobshavn Glacier was accelerating during Greenland's summer months and slowing in the winter. The finding flew in the face of something glaciologists believed about glaciers.

"Ice is a very poor [thermal] conductor, so changes on the surface don't get into the ice very fast," Zwally says. "It takes tens of thousands of years." So how then could an entire glacier react to temperature changes that last only a season?

In considering the question, Zwally remembered flying over a glacier and watching water flowing into it from surface lakes and ponds. The water was channeled into tunnels glaciologists call moulins.

Zwally published the now widely accepted hypothesis that water flows through the moulins all the way to the bottom of the glaciers, where the water acts as a lubricant between the rock and the ice.

The faster glaciers slide downhill, the quicker they melt or break apart in the warming seas. In a 2002 paper in *Science*, Zwally wrote that his melt acceleration theory appears to be more than a seasonal effect. It is "a mechanism for rapid, large-scale, dynamic responses of ice sheets to climate warming," he wrote.

More discoveries like these are expected: Glaciologists say they are just at the beginning of understanding Earth's ice. "Until very recently we didn't really know whether Greenland or Antarctica were shrinking or growing," says Zwally.

Now that there is agreement that both are losing ice, it's up to GRACE and ICESat to tell scientists exactly how much. The results may bring much-needed clarity to the continuing questions over the potential effects of global warming.

FIND OUT MORE www.airspacemag.com

BESIDES ICESat AND GRACE, OTHER INSTRUMENTS are taking the planet's vital signs from orbit. To learn more about what other satellites are studying, visit **www.airspacemag.com**

Flame

WHY THE FIRE IN A PERFECTLY HEALTHY JET ENGINE CAN DIE.

We need vectors to the runway right now sir, we lost an engine, we got only one engine.

TACA 110, New Orleans approach, turn left heading 010, vectors around the storm, understand you have lost an engine, is that correct?

Both engine sir, both engines.

In the early afternoon of May 24, 1988, TACA Flight 110, a Salvadoran Boeing 737 arriving from Belize, was picking its way among thunderstorms ringing New Orleans when the unthinkable happened: Both of the airliner's jet engines quit. Frantically, the crew members tried to restart them. At first they thought they had succeeded: *Okay*, one crew member radioed to controllers as the craft descended through 4,000 feet, *we've got both engines back now.* But relief evaporated less than a minute later. The engines would not accelerate from idle speed, and dangerously rising tailpipe temperatures forced the crew to shut them down again.

I don't think that I will make it, I don't have any power on the engines here sir, so I guess we having to go down, we have to go down, we declare emergency....

TACA 110, there is the interstate highway directly ahead of you....

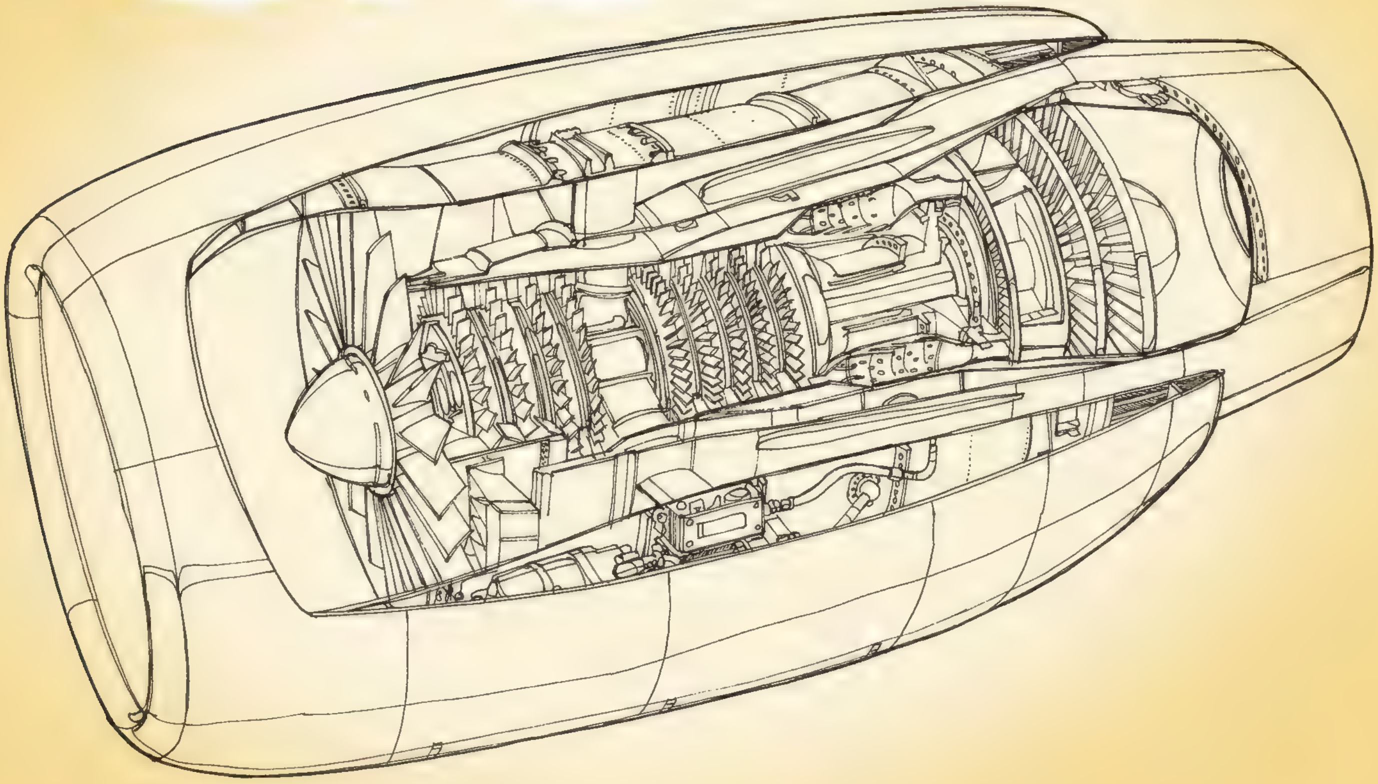
I don't believe we gonna be able to make it there sir, we're at 2,000 and we're losing altitude.... The only thing I do right now is make a 360 and I'll land over the water sir.

TACA 110, I show your altitude now 700 feet.

Seven minutes later another airplane, at the request of the air traffic controller, flew over the area where the 737's radar target had disappeared. The pilot caught sight of the airliner incongruously parked on the embankment of a levee beside Lake Borgne, its escape chutes deployed. With remarkable airmanship, Captain Carlos Dardano had dead-sticked the 737 onto a mile-long patch of rain-soaked earth. The airplane and its passengers

out

BY PETER GARRISON
ILLUSTRATIONS BY HARRY WHITVER



were unharmed.

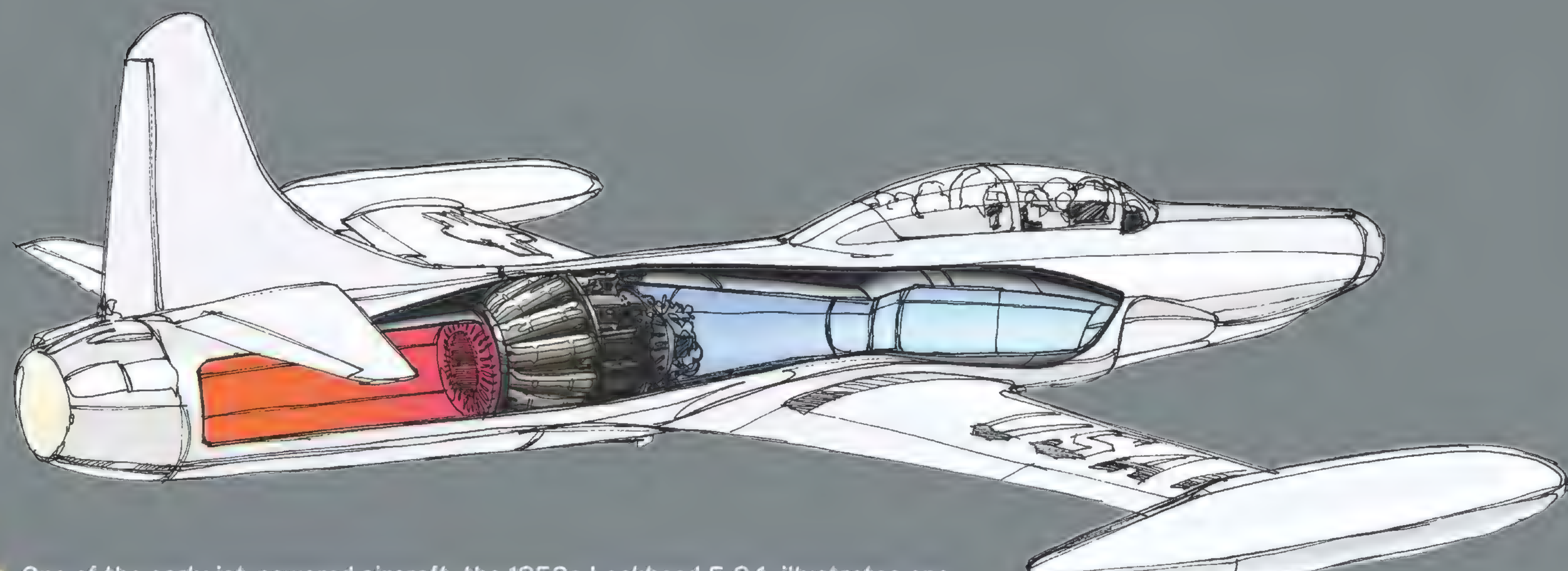
What happened to TACA 110 is called a flameout. The term is casually used for any failure in a turbine engine, but its technical meaning is more narrow: power loss not associated with a mechanical failure. A flameout of one kind or another is thought to occur once in every 100,000 non-military flights.

Three things are needed to keep a jet engine going: fuel, air, and the heat to make them burn. Removing any of the three can cause a flameout. In the case of TACA 110, what was taken away was the "activation energy"—the heat. The engines had been throttled back for descent, and their supply of internal heat was minimal; heavy rain and hail simply doused the fire. The event was not unique. Nine months earlier, an Air Europe 737 descending through rain and hail over Thessaloniki, Greece, had suffered a double flameout. In that case, the crew managed to restart the engines and land without trouble. In 2002, a Garuda Indonesia 737, also descending among thunderstorms, suffered a double flameout over Java. Its crew ditched the airplane in a river; one person died, and there were a dozen serious injuries.

Water and ice aren't the only things that can turn off the fire in a jet engine. Unexpectedly, so can fuel. Obviously, running out of fuel is a good way to stop an engine, but too much fuel can have the same effect, if it comes from the wrong place.

Walt Larimer, a retired U.S. Air Force navigator, remembers an incident from the late 1950s in Morocco. An F-100 pi-

Millions of flying hours have shown the modern airliner engine to be a wonder of reliability, but its smooth operation depends to a degree on its environment. Contaminants or turbulence in the air can disturb its flow through the compressor. If the airflow becomes too uneven, or the air-fuel mix is not properly balanced, a flameout can occur.



One of the early jet-powered aircraft, the 1950s Lockheed F-94, illustrates one reason that military aircraft engines may be more likely to suffer flameout than commercial jet engines. Long air intakes and their position on the sides of the fighter made it more likely that airflow reaching the compressors would be distorted by violent maneuvers or the firing of the fighter's rockets.

lot, a novice at aerial refueling, couldn't get hooked up to Larimer's KB-50J tanker. It took many attempts, but the pilot finally managed to engage the refueling drogue, only to fracture the coupling at the end of the fueling hose a moment later. Jet fuel began to stream out. The fighter, whose engine air intake is in its nose, dropped back and inadvertently slurped up some JP-4. A muffled explosion could be heard from inside the F-100, and flames emerged from its front and rear ends simultaneously. The fighter, its engine spooling down, dropped from sight while a fellow pilot who had been waiting for his turn at the hose shouted restart instructions.

Larimer later learned that the hapless pilot of the stricken jet failed to restart the engine. But he managed to glide back to his base and make a successful dead stick landing on the runway—a semi-miraculous accomplishment in an F-100.

Only a military pilot during a refueling operation is likely to encounter stray JP-4. For the rest of us, the atmosphere can contain even more insidious antagonists. Since 1980, the year Mount St. Helens in Washington state erupted, there have been at least 100 instances of airliners encountering clouds of volcanic ash, often hundreds of miles from the source; the clouds have done more than $250 million in damage to airplanes that unwittingly entered them. In two cases, passenger-carrying Boeing 747s have lost all power in all four engines. The first, a 1982 British Airways flight, glided from 37,000 to 14,000 feet in darkness over the south Pacific Ocean before its crew managed to restart the engines. The second, involving a KLM airplane in 1989, took place in Alaska; there too the pilots managed to restore partial power and land safely.

Volcanic ash, which is highly abrasive, sandblasts an airplane's skin and windows, requiring extensive repairs. Inside the engines, its effects are more varied. Ash grinds away compressor blades and reshapes the airfoils of turbine blades and guide vanes by filling up their concave surfaces. It melts and fuses on the perforated walls of combustors. It plugs up the delicate shrouds and vanes of injectors, whose job is to vaporize the fuel and mix it with just the right amount of air to ensure ignition in the generally over-lean atmosphere of the combustor. All these effects are most disruptive at high altitude, where air is thin and the conditions of combustion are most critical; crews were able to get relights only after long and harrowing glides.

Like all internal combustion engines, a jet engine compresses air, then adds fuel and ignites it. The burning gases in the combustion chamber rush toward the open back end at high speed. On the way, they deliver power—in large engines tens of thousands of horsepower—to a turbine that drives the compressor at the front. The Newtonian equal-and-opposite reaction to gas shooting out the back is the force pushing the engine forward.

The whole process sounds somewhat chancy, and is. Getting a jet engine to run, then keeping it running and under control, is not a simple matter. The early notebooks of Frank Whittle, the Englishman who invented the modern jet engine (independently of, but simultaneously with, a German, Hans Pabst von Ohain), are full of descriptions of dramatically brief tests, shrieking runaways, overheated burners, and melting turbine blades. Air, fuel, and engine speed must remain balanced within certain limits; otherwise, the fire either goes out or consumes the engine around it. The immensely reliable modern jet engine is the fruit of millions of hours and billions of dollars spent getting all the parts just right: the shapes of compressor and turbine blades and the stator blades that guide the flow between them, the lubrication and seals, and the geometry of fuel injectors and igniters. Besides perfecting these components, research has produced materials for the "hot section" in and downstream of the burners, where small parts made of exotic alloys with a melting point of 2,200 degrees Fahrenheit survive, thanks to elaborate and ingenious methods of insulating and cooling, in a steady bath of 3,000-degree gas.

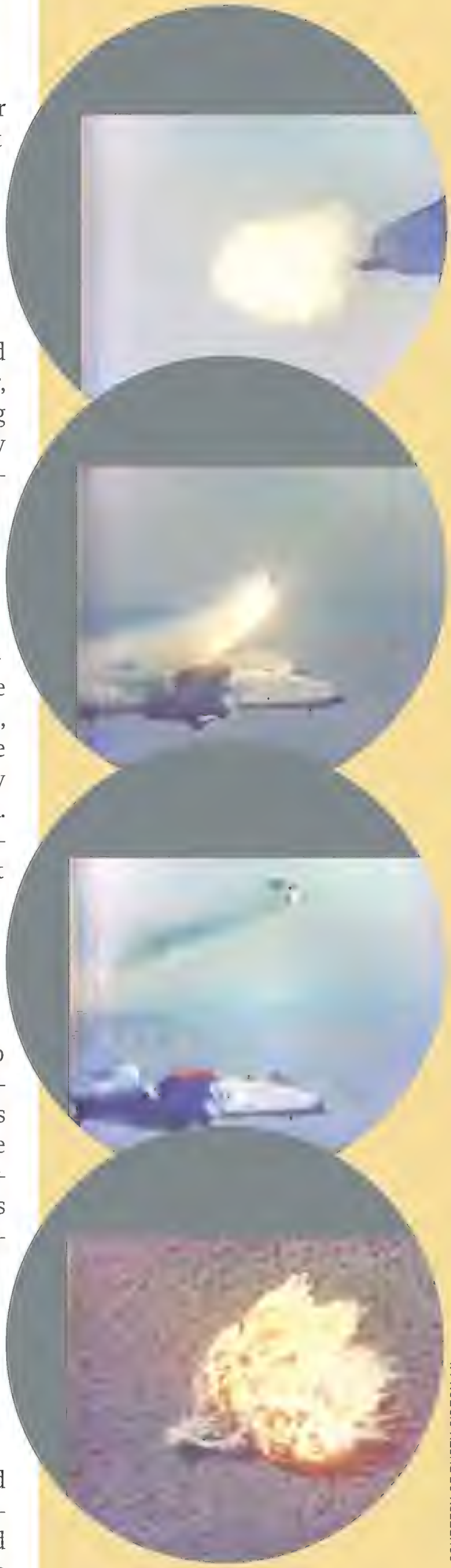
Nevertheless, seemingly small things can still make an engine quit. Very hot or disturbed intake air can do it. Adverse interactions between engines and armament have plagued many military jets. The engines of the A-10 "Warthog," which

are mounted on pylons beside the rear fuselage, suck up much of the gas that blows back from the muzzle of its 4,000-round-per-minute Gatling gun. Occasionally, as Air Force Captain Rusty Gideon learned the hard way (see "All Because of a Little Hot Air," right), ingestion of gun gas can shut engines down.

The F-94 Starfire, a 1950s Lockheed fighter based on the F-80 Shooting Star, would sometimes flame out after firing salvos of rockets, which distorted the flow of air into its side-mounted engine air intakes. Even the relatively modern F-14 experienced interactions between its guns and its Pratt & Whitney TF-30 engines; its gun muzzles were retrofitted with special gas diffusers to alleviate the problem. Actually, the 21,000-pound-thrust TF-30 engine was notoriously prone to flameout for any number of reasons, including—rather inopportunely in the carrier-based Vought A-7, which had only one of them—the jolt of a catapult launch.

Improper inlet flow is said to be "distorted" because jet engines are happiest when the air entering the engine is going in the same direction, and at the same speed, at all points on the engine face. For the short inlets of airliner nacelles and the narrow range of flight attitudes they experience, uniform flow is easy to achieve. Fighters, however, present special challenges to designers. Their engines are normally buried within the fuselage and behind the cockpit, and air has to travel through ducts to reach them. Fighters maneuver violently. Inlets placed alongside the fuselage, like those of the F-14 and F-15, ingest distorted flow whenever the airplane's nose swings to the right or left relative to the flight path. The F-16's intake placement—like that of the Eurofighter, beneath the forward fuselage—tolerates maneuvering better.

Compressor stall—technically called surge—is a much more frequent phenomenon than flameout, and may lead to flameout. Surge occurs when engine speed, airflow, and fuel supply get out of balance and the required distribution of pressure throughout the engine is disturbed. Some or all of the blades in the compressor experience an aerodynamic stall, like that of the wing of an airplane when its nose is held too high. The abrupt pressure drop can generate one or more extremely loud bangs, and, in particular-



COURTESY OF RUSTY GIDEON (4)

Top to bottom: A cloud of flame hangs in front of an A-10's gun after it fires. Both engines have flamed out. The pilot ejects. The A-10 crashes near Edwards Air Force Base in California.

All Because of a Little Hot Air

EDWARDS AIR FORCE BASE, June 1978. Major Francis "Rusty" Gideon was doing routine ordnance testing in an A-10 "Warthog," which has a 30-mm Gatling gun in the nose that fires about 4,000 rounds a minute. He was supposed to fire 100 rounds each from three batches of ammunition from three manufacturers.

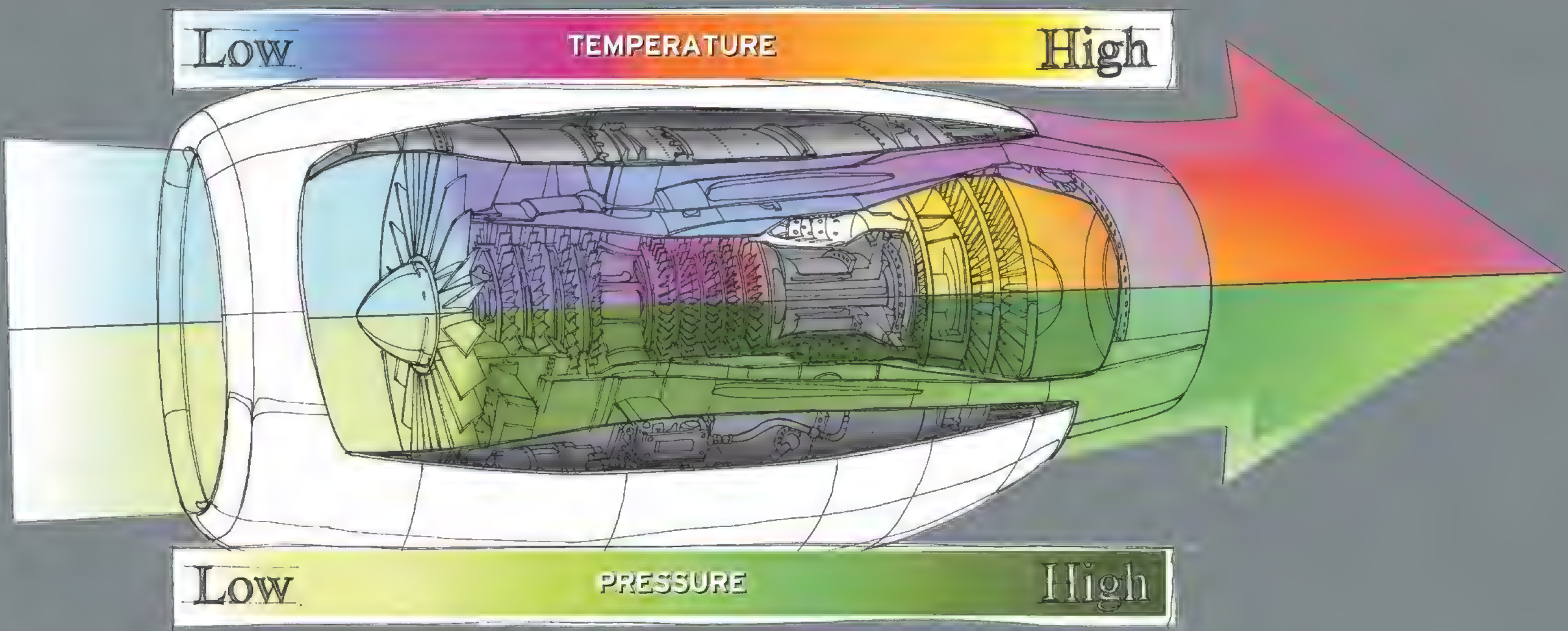
"We were at 6,000 feet. I got off the first two bursts without anything unusual happening. Some smoke and gas always comes out of the gun and streams back along the sides of the plane, but it doesn't affect the engines. But when I fired off the third batch of rounds, you know they put nitrate in the powder to prevent unburned stuff from blowing out of the gun, but I guess there wasn't enough, because this time I saw a sort of burning cloud that just hung in front of the airplane as the gun was firing. And then when I stopped firing I could tell I had a problem. My engine temps were going up and my speed was coming down.

"Both engines had flamed out. I tried to restart. There's a certain envelope of speed and altitude and temperature for a relight. I had to wait for the temps to drop before I could restart, and we were already pretty low. The plane comes down about 4,000 feet a minute. It was a race between the altimeter and the temperature gauge. I couldn't get a restart, and finally at about 2,500 feet I ejected. Broke my neck in the process. We never knew for sure how that happened."

Gideon recovered from his injury and retired from the Air Force as a major general. His chase plane filmed the entire sequence, from test to ejection to crash.

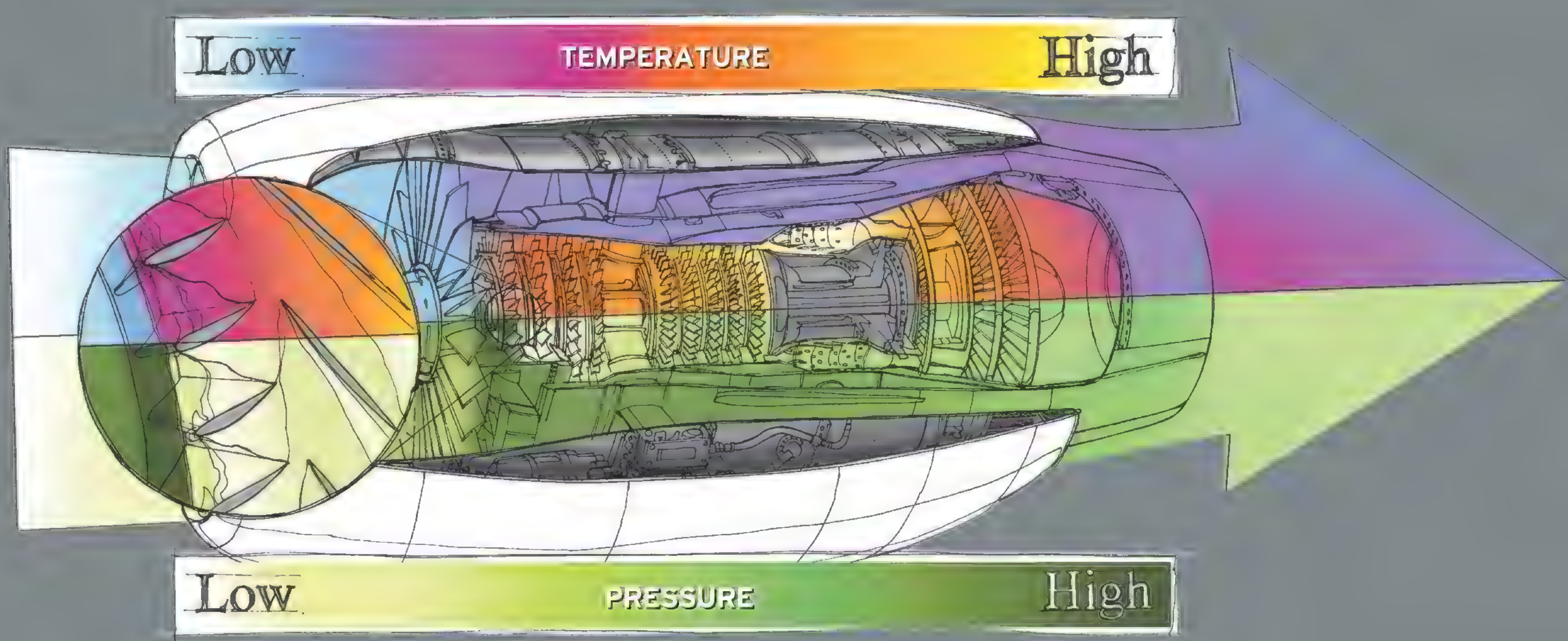
ly dramatic cases, the flame from the combustor, no longer forced backward by incoming compressed air, can shoot out the front of the engine. Usually the engine recovers on its own. Frank Smith, a former Navy A-7 pilot, recalls a particularly startling compressor stall that happened during a practice dogfight in 1970. His opponent "went from 250 yards astern to 100 yards ahead in about one second while I experienced a complete end-swap and the biggest noise I ever heard from an aircraft that remained in one piece. But the engine kept running and rpm barely dropped before I was able to regain control. Hell, I really didn't do anything but hang on."

Surges do not always clear automatically; sometimes they are "locked in," rotating in place within the compressor. Then, rising temperatures in the hot section force the pilot to shut the engine down. Loss of an engine affects other aircraft systems—hydraulic, pressurization, and electrical—all of which are supplied by engine-driven components. There are backup systems, but restarts can still be surprisingly difficult because of the distracting secondary effects of losing power.



The Importance of Smooth Airflow

EACH ROW OF BLADES in a jet engine's compressor produces a small jump in pressure, a process indicated in the above illustration by a gradual darkening green. By the time the air arrives at the combustor it can be, depending on the engine configuration, 40 times denser than the air entering the intake. The air's temperature also increases during this process. The blades in the compressor stages can stall in the same way an airplane's wing stalls if the flow of air over it becomes disturbed or detached. Increased leakage of air around the tips of the compressor blades can also interrupt the steady flow. "Stall cells" form between the blades, and the increase in pressure from row to row cannot be maintained. The initial drop in pressure is indicated in the illustration below by a white area just aft of the row of blades where the air has stalled. The air downstream of the stall is at that moment still at high pressure. If enough blades stall, the difference in pressure can cause oscillations in the airflow and can sometimes cause the flow to stop or even reverse. In most cases the condition is brief and will correct itself, but a violent stall can trigger a flameout.



Even within its operating envelope, however, the higher a jet flies, the narrower the "surge margins" that define how far conditions within the engine can stray from the optimum before it quits running. At sufficiently high altitudes, jet engines flame out simply because they run out of oxygen.

Not all flameouts are accompanied by noise or vibration or by any obvious triggering event. In some cases, especially on multi-engine airplanes, one engine may spool down unnoticed by the pilot, while autopilot and autothrottle conspire to mask the thrust asymmetry. In a few instances, crews have temporarily lost control because they failed to realize that one engine has stopped producing thrust.

A fatal accident in 2004 illustrates the potentially dire consequences of inattention to engine parameters and the unexpected difficulties that can beset restart attempts. Two pilots flying a Canadair regional jet to its next departure location decided, on a lark, to take the airplane up to its 41,000-foot ceiling, where neither had ever been. They programmed the autopilot to climb at a fixed rate. As the airplane ascended into ever thinner air and the engines produced less and less thrust, the autopilot had to keep reducing speed in order to maintain the commanded climb rate. The crew did not notice anything was wrong until both engines flamed out.

The pilots turned to the restart checklist, which first required descending rapidly to a lower altitude. Meanwhile the engines spooled down, and unequal cooling of closely fitting seals in the compressor caused them to bind—a condition now dubbed "core lock." The engines would not spool up, either from windmilling or with the help of the auxiliary power unit. By the time the crew realized that the engines would not come back, they were too low to reach the nearest landing field. The aircraft crashed a couple of miles short of a runway; both pilots were killed.

Engines that have flamed out and that have not been damaged by, say, a violent compressor surge can, in principle at least, be restarted. The difficulty of restarting, and the time it takes, depend on several factors, one of which is how much the engine has spooled down. With sufficiently high forward speed and sufficiently low altitude—generally above 250 knots and below 25,000 feet—engines can windmill up to a speed sufficient to permit ignition; then they gradually bootstrap back to operating speed and compression. Although jets, like any airplane, can glide without power—airliners can progress 10 miles or more horizontally for every mile of altitude they give up—the speed required for a windmilling start is much higher than the best glide speed, and so altitude melts away rapidly during restart efforts.

Military jets are regularly tested for restart ability—for example, after an engine upgrade or modification. In twin-engine airplanes it's routine work, but when an airplane has only one engine to begin with, it can occasionally get tense. Art Nalls, now retired from the Marine Corps, recalls a wintertime test of a TA-4J—a training version of the single-engine A-4 Skyhawk—at Edwards Air Force Base in California. The giant lake bed, an alternate landing site for space shuttles, is normally bone dry, but recent rains had soaked the ground and left it largely flooded.

The test card called for restarts at selected points along the edge of the restart envelope; if the engine failed to relight, Nalls would move to the "heart of the envelope," where the engine was considered sure to start. "One of the last points was a low-altitude, slow-airspeed point that left little margin for error," he remembers. "Only a small portion of the lake bed was available for landing, and it was soft. Quite possibly the airplane could flip over. But it was legally usable and met the criteria of our test plan, so we elected to continue. We were almost done with the project, everything had worked normally so far, and get-home-itis had started to set in."

Already at a low altitude when the test began, Nalls found it impossible to restart the engine. Only when he was below 1,000 feet, seconds away from a landing on the muddy lake bed, did the engine finally relight. It later turned out that the cause of the trouble had been a malfunctioning ram air turbine—the backup electrical source for the engine's igniters.

Nalls was a test pilot, and test pilots feel strong pressure to bring back the ship in one piece. Under the same circumstances, a service pilot whose jet had flamed out would long since have ejected. The likelihood of making a successful dead stick landing in a jet fighter is considered so slight that the military services have wavered on whether "flame-out approaches" should be taught at all.

Though the reliability of jet engines is far better than that of the reciprocating engines that they largely replaced half a century ago, the danger of flame-outs hasn't disappeared. Flameouts are a natural consequence of the way jet engines work. They live on an island of stable operation—a dynamic balance of powerful forces—ringed by a sea of instability.

Flameout Guard

AN INNOVATION that appeared less than a decade ago has done much to make flameouts a thing of the past. It is the FADEC: full authority digital engine control. The operative words are "full authority." The FADEC is a completely electronic engine controller. With a FADEC, pilots no longer have direct control of engine parameters. Instead, an electrically hardened, highly redundant computer constantly monitors conditions inside the engine and adjusts fuel flow, ignition, vane positions, pressure bleeds, and idle speeds to keep the engine at the very center of its island of stable operation. A sudden throttle movement that would have produced a compressor stall in a conventionally controlled engine is invisible to a FADEC-equipped one. The computer intercepts the pilot's message – "Give me power, fast!" – and brings up the power at the engine's best rate, but no faster.

FADEC is what turbine engines have always needed: a pilot who does nothing but check the health of the fire hundreds of times a second. No doubt engines will still occasionally find ways to flame out, but for FADEC-equipped engines it will be much harder work than ever before.

Norman Rockwell's Ghost

A young space artist helps America's favorite illustrator paint the moon. *by* Pierre Mion

On a Sunday morning in November 1966, my wife and I were having breakfast at our home in Bethesda, Maryland, when the phone rang. I answered it, and the operator said, "Pierre Mion, please." I said, "Speaking." She then said, "Go ahead, please." An older voice came on the line, saying, "My name is Norman Rockwell, and I'm an illustrator." And I said, "Sure. And my name is Mickey Mouse." The caller again said his name, but I didn't believe him, thinking it was a friend of mine who frequently played practical jokes on me. I kept saying, "Come on Billy. I know it's you." After a couple more minutes of this, he became frustrated, saying, "I'm not Billy. I'm 72 years old. Ask me any questions you would like." Then I began to think: What if it really is Norman Rockwell and he hangs up? So I said, with tongue in cheek, "Go ahead Mr. Rockwell, what can I do for you?"

He told me that *Look* magazine had commissioned him to do three paintings depicting the first manned landing on the moon, which at this point was over two and a half years away. He added that he was having problems with the subject and could use some help and advice. Now I knew it must be a hoax because not only would Norman Rockwell not call me, but surely he would not need my advice.

He went on to say he had seen an article I had illustrated in *National Geographic* magazine four years earlier about robotic spacecraft landing on the moon, liked what he saw, and felt I must be familiar with the subject of space. He then asked me if I could come up to his studio in Stockbridge, Massachusetts, to help him. I asked when he would like me to come, and he said, "How about tomorrow?" I said okay, and

PHOTO BY MOLLY ROCKWELL/COURTESY NORMAN ROCKWELL MUSEUM

he told me to make a reservation to fly to Hartford/Springfield. After I booked the flight, on Allegheny Airlines, I called him back: He told me his friend Ken Hall, who owned the local gas station and garage, would pick me up at the airport. He said, "You can't miss him. He's well over six feet and quite large." I told him I would see him tomorrow.

Now, at this point, I still was not sure this wasn't a practical joke, but if it was, it was becoming pretty elaborate. I wondered if, when I arrived in Stockbridge, my crazy friend Billy would be waiting to greet me with "Boy, I really got you this time!"

When I arrived at the house, I immediately went into the studio, an old converted carriage house. Rockwell, a thin man with thick silver hair, was waiting for me, and as soon as I met him, I tried to give a speech I had prepared and started by calling him Mr. Rockwell. He told me to call him Norman and said how pleased he was I had come. We went right to his easel, on which was an oil painting in progress of an astronaut climbing down the ladder from the lunar lander, about to place his left foot on the moon's surface. Rockwell put his arm around my shoulders and started asking me questions about technical details and the colors of the lunar surface.

During the design and construction of most spacecraft, details change on a daily basis, and NASA people kept sending Rockwell updates on the lunar module at a confusing rate. What he needed was someone who had my experience with the subject of space to make some final decisions for him so he could finish the painting. As a boy, I had painted imaginary rockets, and later I honed my skills working for a design studio that frequently got contracts from NASA. I had also worked on several Apollo program illustrations, so I gave him my opinion on several details, which he accepted.

At the end of a day of productive discussion, Rockwell told me he did not have enough time to complete all three paintings for the *Look* assignment. Besides the first-footstep painting, he had been asked to do a generic-astronaut portrait, as well as the lunar ascent stage's liftoff from the moon. Rockwell asked me if I could do the third painting for him, and he would add his touches and sign it. I was so speechless I could not answer him right away, so he said of course he would pay me what the *National Geographic* would. I still had not answered him, so he said, "Oh, hell. I'll pay you whatever you want." I couldn't believe that Norman Rockwell wanted me to ghost a painting for him. I told him I would be delighted to do it and that the *National Geographic* (at that time) would pay me $1,000 for a similar effort. He said that was fine, so I left shortly after to make the last flight home.

Space artist Pierre Mion (opposite, at right) began a 12-year friendship with Norman Rockwell in 1966, after the older painter asked for advice on executing space paintings, including Rockwell's "Man's First Step on the Moon."

A week later, after I finished the painting, I called Rockwell and asked if I should send it up to him. He said he would rather I bring it up so we could compare our two paintings. Needless to say I was extremely nervous, but I made reservations for the next day (Rockwell later reimbursed me for the airfare) and once again was met by Ken Hall at the airport. I kept wondering what kind of touches Rockwell would want to add to my painting. Truth be told, I thought I had done a nice job, and adding touches might only mess it up.

When I arrived at Rockwell's studio, he immediately asked me to unwrap the painting. You can imagine how uneasy I felt. He said, "Oh, this is really quite good. Better than I thought it would be. I mean, I thought it might look something like an engineer's drawing." Realizing he was putting his foot in his mouth, he again said how nice it was and that he liked my colors better than the ones he had used on the first-footstep painting. He asked me if I could stay a few days to bring his painting closer to mine in color. I agreed, and during that time, I learned that Rockwell was an absolute workaholic: He rose at dawn every day, prepared himself a breakfast of two boiled eggs and fresh-squeezed orange juice, then headed to the studio. He painted all morning (either standing at his easel or sometimes sitting before it in a wooden chair), broke for lunch, then resumed painting until sundown.


BY PIERRE MION/NASM

Mion's painting of an Apollo lunar module leaving the moon appeared in a *Look* magazine story illustrated by Rockwell; the article favorably linked Mion with his famous friend.

Fortified by the breakfast that Rockwell had prepared for me, I started working on his painting, drawing the antenna atop the spacecraft, repainting the stars, and drawing and painting the interior of the spacecraft as seen through the windows. He was quite embarrassed to be receiving this kind of help, including having one of his paintings done by someone else. He had never had anyone do this for him. To put him at ease, I reminded him of the Baroque painter Peter Paul Rubens, who had 40 students working in his studio; when he liked one of their paint-

ings, he would sign his own name to it. There are still some Rubens paintings that are of indeterminate origin.

One day while I was working on his painting, Rockwell was relaxing on a cushioned bench under the large north-facing window, smoking his usual pipe, and he said, "You know Pierre, I'm getting to like this Rubens idea."

The three paintings were done by *Look*'s deadline, and when they were published, the one I had done had not been "touched" or "signed" by Rockwell. The caption read: "Norman Rockwell, assisted on this painting by artist Pierre Mion, shows the departure of Apollo astronauts from the moon...." I could not have asked for more. If *Look* had given me full credit for the painting, people would have assumed Rockwell and I had worked independently. But because the caption linked the two of us, it gave me a great career boost. And by the way, Rockwell paid me $1,500 for my work instead of the $1,000 he had offered.

On another assignment, we went to Florida to do research and photograph the three Apollo 11 astronauts (Neil Armstrong, Buzz Aldrin, and Michael Collins) for a large painting Rockwell was going to do for *Look* to commemorate the first manned lunar landing. NASA had arranged for us to photograph Armstrong, Aldrin, and Collins in the manager's office of the Holiday Inn in Cocoa Beach, where the astronauts were staying. Collins, who walked into the office first and was delighted to meet Rockwell, was extremely humble and most polite. When Armstrong and Aldrin came in a few minutes later, they seemed completely indifferent and unimpressed by meeting Rockwell and were obviously annoyed at this foolishness. Looking at Armstrong's eyes, I felt as if I was looking at some sort of alien, cold as hell.

Before this trip to Florida, Rockwell thought he might paint the three Apollo 11 astronauts surrounded by many of the world's explorers, such as Columbus, Magellan, and Admiral Richard E. Byrd. I told him that might be sort of old-fashioned, and suggested he show the three astronauts flanked by numerous NASA and industry people who had helped make the first manned moon landing possible. He liked the idea, and this is what he eventually painted. He also had the Holiday Inn manager photographed, and, believe it or not, put him in the final painting in the lower righthand corner, portraying him as NASA staff. Rockwell told me the reason he depicted all of the heads as profiles was because it took much less time to paint only half of a face. I assisted him back at his studio by painting the background, the Apollo assembly building and launch tower, and

Rockwell used oil paint to make a generic-astronaut portrait (above left), which *Look* published in 1966. Earlier, the magazine had commissioned him to portray John Young and Gus Grissom suiting up before their March 23, 1965 Gemini flight.

the astronauts' helmets and suit valves. The *Look* article illustrated with this painting, as well as three others by me, wasn't published until right after the Apollo 11 crew's return to Earth on July 24, 1969. (No one was certain the mission would succeed; had it failed, there obviously would have been no congratulatory article.)

Rockwell and I worked together on other projects through the years and continued our friendship until his death in 1978. At one time, while visiting Washington, D.C., to promote a book of his work, he and his wife Molly went with me to an airport in Warrenton, Virginia, where I took each for a flight in a sailplane. I must say Molly had a better time than Norman. While in the air, he kept repeating, "As long as I know Pierre is at the controls, everything will be all right." It dawned on me that I had the safety of this great artist in my hands.

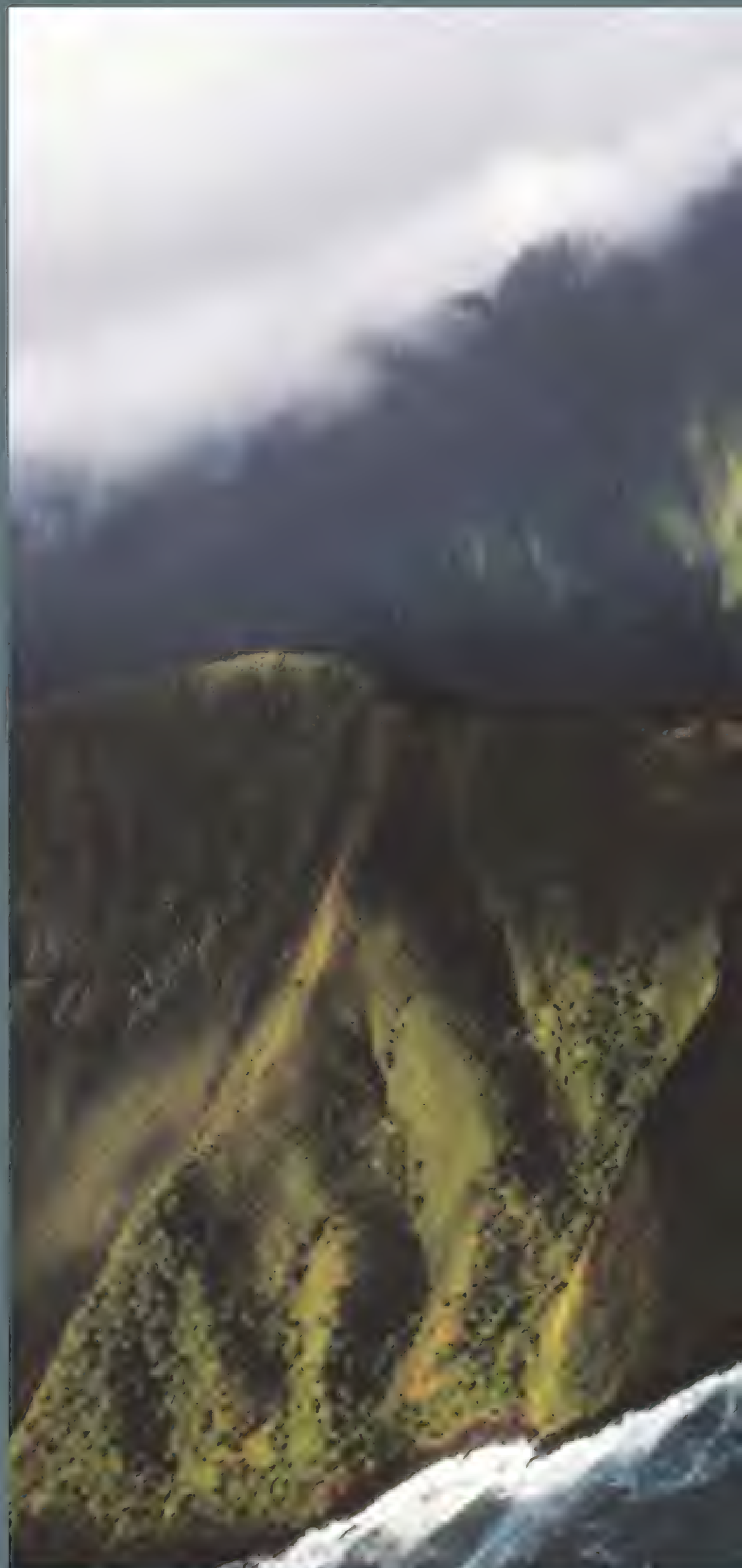
Mion assisted Rockwell on "Behind Apollo 11" by painting the background, launch tower, and astronauts' helmets.

"BEHIND APOLLO 11" BY NORMAN ROCKWELL/NASM/LICENSED BY NORMAN ROCKWELL LICENSING, NILES, IL.

Rockwell's Space Legacy

In 1965, Allen Hurlburt, art director of *Look*, commissioned Norman Rockwell to visit NASA facilities and paint whatever interested him. "I am fascinated with the space program," Rockwell remarked to a friend. "There is nothing that excites my admiration and interest so much as this wonderful project, and the brave astronauts, and I am proud to have a tiny chance to celebrate it in pictures." Rockwell produced five space paintings for *Look* between 1965 and 1969. Frederick C. Durant III, assistant astronautics director of the National Air and Space Museum, was so impressed with the works that he borrowed and exhibited the five paintings in the Smithsonian's Arts and Industries Building, where the Museum was then housed. Eventually, Rockwell would donate all five of his paintings, and a sixth by his friend and collaborator, Pierre Mion, to the Museum. "I can't think of a place that I would be prouder to have them kept," Rockwell remarked to Durant, adding that he hoped "they aren't down in one of your deep cellars all the time." He need not have worried. All six paintings remain on display in the public galleries or executive offices of the Museum, where they continue to remind visitors of mankind's drive to explore.

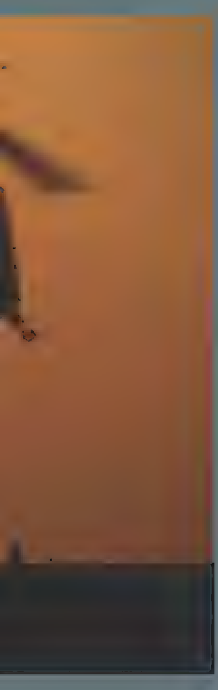
TOM CROUCH, THE NATIONAL AIR AND SPACE MUSEUM'S SENIOR CURATOR OF AERONAUTICS, MANAGES THE MUSEUM'S ART COLLECTION.



SIGHTINGS

These photographs may look familiar to you. That's because the man who made them exerted such influence in the small world of aviation photography that many of the pictures of aircraft you've seen—in these pages and elsewhere—bear his mark. George Hall, who died last April after heart surgery, treated airplanes as living things; he got up close to them in the air and on the ground and made them appear almost to breathe. An aviation fan, he knew airplanes and helped spread that knowledge through his stock photo agency, Check Six.

This selection is vintage Hall. He shot Marine Corps Reserve F-4 Phantoms (right, top) above a Hawaiian coastline with a camera tucked in a pod he devised and hung on the wing of the F-4s' squadron mate. The fighters appear to be able to call on the power of the cliffs and sea for backup. Other George Hall classics capture the personalities of his subjects. For a picture of a shiny new 737 (above) exuberantly leaving the runway, Hall asked the pilot to lift the gear early, knowing the retracting struts would add energy to the picture. He made a swarm of UH-1 Hueys (right) appear insect-like and busy. For the SR-71 Blackbird (far right), Hall used tungsten film to create deep blue and a sense of mystery, and silhouetted its famous form. He also got the aircraft to do what spyplanes do: You are not looking at the SR-71; it is looking at you.



COURTESY DANIEL J. CLEMONS

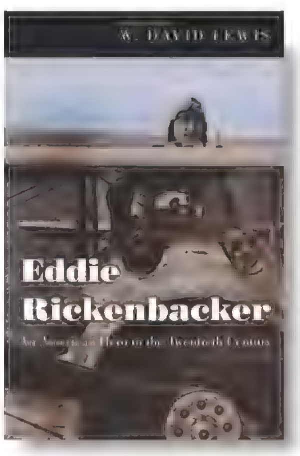
Left to right: Joseph Eastman, James Meissner, Rickenbacker, Reed Chambers, and Thorne Taylor lean against a Spad XIII in Rembercourt, France, October 18, 1918.

The Great American

Eddie Rickenbacker: An American Hero in the Twentieth Century

BY W. DAVID LEWIS. JOHNS HOPKINS, 2005. 720 PP., $35.00.

For Americans who lived through it, one of World War II's defining moments was the return of Eddie Rickenbacker after a mid-Pacific ditching in October 1942 (see W. David Lewis' "The Rescue of Eddie Rickenbacker," Aug./Sept. 1998). If the iconic "Captain Eddie" could survive three weeks on a raft, the Japanese didn't stand a chance.



The uneducated son of Swiss immigrants, with a mother he adored and a father who whipped him, Rickenbacker constantly reinvented himself while growing up in Columbus, Ohio. He took the nicknames Edd, Eddie, Rick; he gave his middle name as Victor, then Bernard, then Vernon; and he changed the family name from Rickenbacher, to make its less obviously Germanic during the war that began in 1914.

Having gone from shop boy to mechanic to famous race-car driver, he joined the U.S. Army in 1917 as General "Black Jack" Pershing's chauffeur. Once in France, he got into aviation, becoming commander of the 94th Pursuit Squadron and America's "ace of aces" with 26 aerial victories. Postwar, he went through careers at a dizzying pace: lecturer, manufacturer (the Rickenbacker was the first U.S. production automobile with four-wheel brakes), founder of Florida Airways, owner of what became the Allison division of General Motors, Cadillac spokesman, owner of the Indianapolis Speedway, and vice president of the U.S. Fokker company.

Many of his enterprises lost money, but Rickenbacker could always find an admirer to bankroll his next venture. The last and best of these was Eastern Airlines, which he ran with arrogance and charm, convinced all he needed was to "put asses in seats." For a time it was the country's most profitable airline. Alas, government regulators prevented him from competing on price; that, plus a bad choice of jetliners, put Eastern on the route to bankruptcy.

Author W. David Lewis is a bit shaky on aviating (when an airplane stalls, it's the wings and not the engine that lose authority) and history (China's Flying Tigers weren't airplanes but the men who flew and maintained them). But he has Captain Eddie nailed to perfection.

DANIEL FORD IS PREPARING A NEW EDITION OF *FLYING TIGERS: CLAIRE CHENNAULT AND THE AMERICAN VOLUNTEER GROUP.*

Why Air Forces Fail: The Anatomy of Defeat

EDITED BY ROBIN HIGHAM AND STEPHEN J. HARRIS. UNIVERSITY PRESS OF KENTUCKY, 2006. 382 PP., $39.95.

As the televised crosshairs fell on bridges, airshafts, and even individual windows during Operation Desert Storm in 1991, the tactical aircraft seemed to rise to primacy as the decisive weapon of warfare. But it was a fleeting promise: More than a decade later, improvised explosive devices, intractable sectarian politics, and the complexities of nation building in Afghanistan and Iraq have returned us to the question asked since the first broadsword was forged: Do we have enough troops to do the job?

Through 11 case studies authored by military theorists, Air Force officers, and historians, editors Robin Higham and Stephen J. Harris present a lively range of essays that examine the most noteworthy of the 20th century's failed air campaigns. There is

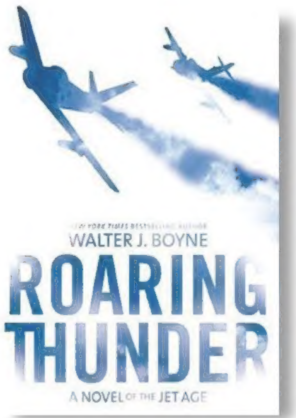
much to learn from the better known subjects—the reliance on obsolete aircraft that hobbled the early American effort in the Pacific in World War II, for example—to the more arcane, such as the miscalculations that doomed the Argentine air force during the 1982 Falklands War, or the seeds of defeat of the German and Austro-Hungarian air forces that were planted nearly a decade before World War I.

Despite a well-written, but brief, conclusion that links common themes among the essays, the reader is left to his or her own research for detailed contrasts and comparisons. But no matter: At a time when the debate about the limits of airpower is as fresh as ever, *Why Air Forces Fail* is a timely read.

JOHN SOTHAM IS A FORMER ASSOCIATE EDITOR OF *AIR & SPACE/SMITHSONIAN*.

Roaring Thunder: The Birth of the Jet Age

BY WALTER J. BOYNE. FORGE, 2006. 304 PP., $24.95.



Many people know that Germany's Heinkel He 178 made the world's first successful jet aircraft flight on August 27, 1939. Until now, however, no one transformed this aviation milestone into the stuff of high drama.

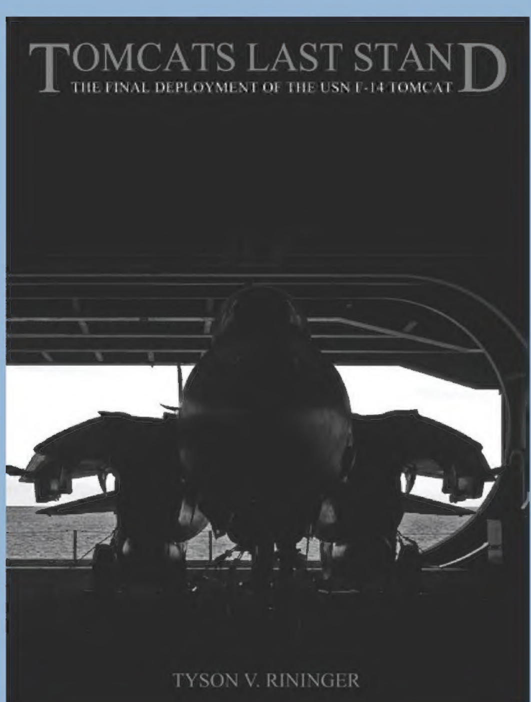
Walter Boyne's latest book is fiction—the first of a trilogy of novels that begins with the jet era. Most characters in *Roaring Thunder* are novelized versions of real jet pioneers—Germany's Hans Von Ohain, Britain's Frank Whittle, America's Clarence "Kelly" Johnson. Here, they interact with fictitious characters who live, love, and fly, in an account rich with details drawn from real life.

This mix of reality and fiction is both the strength and weakness of *Roaring Thunder*. The viewpoint shifts constantly, and the characters sometimes seem to have the depth of stick figures. One of the few authors to have bestsellers on fiction and non-fiction lists, Boyne is a retired Air Force command pilot and a former director of the National Air and Space Museum, so the aeronautical material is authentic and fascinating.

ROBERT F. DORR, A U.S. AIR FORCE VETERAN, IS THE AUTHOR OF *MARINE AIR* (BERKLEY CALIBER, 2005).

TOMCAT GALLERY

RICHARD VANDER MEULEN



As we say goodbye to a favorite fighter, several world-renowned photographers and writers have compiled their best stories and photos of the powerful F-14 into high-gloss, brilliant-color coffee table books.

Anytime, Baby: Hail and Farewell to the U.S. Navy F-14 Tomcat
by Erik Hildebrandt. Cleared Hot Media, 2006. 180 pp., $49.95.
A love letter (with color pictures) to the various achievements of U.S. Navy F-14s.

Grumman F-14 Tomcat: Bye-Bye Baby! Images & Reminiscences From 35 Years of Active Service
compiled by Dave Parsons, Bob Lawson, and George Hall. Zenith Press, 2006. 160 pp., $40.00.
Writers Dave Parsons and Bob Lawson, along with the late photographer George Hall, compiled hundreds of stories and pictures of the F-14 for this lively book.

Tomcat's Last Stand – The Final Deployment of the USN F-14 Tomcat
by Tyson Rininger. Scheduled publication mid-2007.
A memorial to two squadrons – the VF-31 "Tomcatters" and the VF-213 "Fighting Blacklions" – that follows the pilots and their aircraft from the last cruise to the eventual transition to the new F/A-18 Super Hornet.

CALENDAR

August 5 & 6
Thunder Over Michigan. This year's airshow will salute the Douglas Skyraider and the Supermarine Spitfire. Willow Run Airport, Ypsilanti, MI, (734) 483-4030, *www.yankeeairmuseum.org*.

August 18 & 19
Okie Derby Air Race. Sponsored by the Oklahoma chapter of the Ninety-Nines. Wiley Post Airport, Oklahoma City, OK, (405) 378-3602, *www.okiederby.info*.

September 2
Warbirds Forever!—Keep 'em Flying Seminar. The event will conclude with a flight demonstration by an aircraft in the collection. Planes of Fame Museum, World War II Cal-Aero Field, Chino, CA, (909) 597-3722, *www.planesoffame.org*.

September 2 & 3
Spitfire Anniversary Airshow. American Air Museum, Cambridge, United Kingdom, phone: 44 (0) 1223 499 305, *aam.iwm.org.uk*.

September 9-11
Last Chance Labor Day Fly-In. Shreveport North Airport at Footlight Ranch, Wellsville, PA, (717) 432-4441, *www.footlightranch.com*.

September 13-17
43rd National Championship Air Races & Airshow. U.S. Air Force Thunderbirds will perform. Reno Stead Field, Reno, NV, (775) 972-6663, *www.airrace.org*.

September 30 & October 1
California International Airshow. Salinas Municipal Airport, CA, (888) 845-SHOW, *www.salinasairshow.com*.

EAA Virginia Regional Fly-In. Dinwiddie County Airport, Petersburg, VA, (703) 590-9112, *www.vaeaa.org*.

Organizations wishing to have events published in Calendar should fax press releases to (202) 275-1886; e-mail them to editors@si.edu*; or mail them to* Calendar Air & Space/Smithsonian*, MRC 951, P.O. Box 37012, Washington, DC 20013-7012.*

CREDITS

A Hard Day's Night. Bill Robinson flew 106 combat missions in Vietnam. After 10 years as an Air Force officer and 25 years as a civilian engineer, he's back to making landfalls – this time along the Atlantic coast in his sailboat.

Nikola Tesla's Curious Contrivance. A.J.S. Rayl is a science writer in Malibu, California.

Where the War Began. Retired U.S. Air Force pilot Ralph Wetterhahn has written three books. He is now researching the fate of U.S. pilots who disappeared inside the Soviet Union during the Korean War.

How Things Work: Swing Wings. Joe Pappalardo is an associate editor at *Air & Space/Smithsonian*.

Persian Cats. Tom Cooper, a native of Vienna, Austria, is the author of *Iranian F-14 Tomcat Units in Combat* and *Iranian F-4 Phantom II Units in Combat*.

The Grumman Cats. According to family lore, Brian Nicklas' first word was "airplane." When not chasing aircraft with a camera or restoring Ford Mustangs, he is a reference archivist at the National Air and Space Museum.

Stronger Than Dirt. Trudy E. Bell wrote "When Stars Collide" for the Aug./Sept. 2005 issue.

Show Me the Way to Go Home. Roger A. Mola is writing a documentary on Operation Skyshield ("This Is Only a Test," Feb./Mar. 2002).

Keep Watching the Ice. Ben Iannotta is a journalist living five feet above sea level in Summerland Key, Florida.

Flameout. Peter Garrison has had a crankshaft break in flight, but his only first-hand flameout experience has been with barbecues.

Norman Rockwell's Ghost. Pierre Mion is currently working on seven commissioned fine art paintings.

FORECAST

IN THE WINGS

ERIK SCHULZINGER/ LOCKHEED MARTIN CORP.

The F-35B may be lethal, but its weight problem could have been a real killer.

Warplane on a Diet

When Lockheed's marquee fighter, the F-35B, came in several thousand pounds overweight, a cadre of engineers had to save the day.

Just Here for the View

Space station tourists share their orbital adventures, saving readers the cost of a ticket.

What's Beneath Mars?

Getting under the surface of the Red Planet will take ingenuity and an exceptional drill.

The Jet in Your Garage

Ever wonder why the idea of very light jets took so long to catch on? We'll explain.

Tense Touchdowns

Commercial aircraft must take uncomfortable measures when landing at Baghdad International Airport.

"One small step for dog. One giant setback for the invisible fence."

Fly Like a Broken Eagle

The National Advisory Committee for Aeronautics was the nation's primary aeronautical research body before it became part of the National Aeronautics and Space Administration in 1958. When the NACA sought a fix for an airplane's design, it usually did it with hardware. For example, when the Lockheed P-38 Lightning encountered compressibility effects in high-speed dives, the NACA devised a dive brake—a hinged flap that swung down from the lower surface of the wing.

NASA DRYDEN

NASA's NF-15B is a fast learner.

Today, agency engineers are more likely to solve problems with software. At NASA's Dryden Flight Research Center in California, a highly modified NF-15B research aircraft is in the second phase of a project designed to enable even badly damaged aircraft to survive. At its heart is what computer scientists call a "neural network."

According to project manager Michael Toberman, 17 flights have been completed with the new system. "When the airplane is flying, there's a [software] model that says what it should be doing, and there are sensors that tell it what it's really doing. The difference between the two is a feedback error [signal] that is sent to a neural network, which augments actual flight control computer commands to make changes to get the airplane to do what it is supposed to be doing." Research has simulated damage to flight controls—the loss of an aileron, say. When the pilot moves the stick left or right to roll, sensors tell the computer that the rate of roll is incorrect. Additional controls are activated to enhance the roll rate; in this case, that might include the rudders and asymmetric deflection of both horizontal stabilizers.

Like a brain, the system learns as it compensates, so the next time the stick moves, it will automatically augment the pilot's control input. "The more you fly it, the more it adapts, and within 30 seconds it's finished learning," Toberman adds.

Last February, NASA reached a milestone when it compared handling qualities with the system turned on and turned off. Even more acute-failure modes will be tested in the next phase, scheduled for November.

Toberman says follow-on research proposals have been filed with NASA headquarters. The concept has potential to improve performance aboard everything from airliners to NASA's new Crew Exploration Vehicle.

GEORGE C. LARSON, MEMBER, NAA

National Aeronautic Association

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LOGBOOK

NAA Honorees

Annie Castor Glenn, wife of astronaut and former Senator John Glenn, recently received the 2006 Katharine Wright Award in honor of her 60 years of service, both in support of her husband and in the advancement of aviation.

The award, established in 1981 by the Gates Learjet Corporation, is given annually to a woman who has provided encouragement, support, and inspiration to others, or has made a personal contribution to the advancement of the art, sport, and science of aviation and spaceflight over an extended period. The award was named in honor of Orville and Wilbur Wright's sister, who used the money she earned from teaching to purchase supplies for her brothers' experiments and contributed ideas to their projects. The award is co-presented by the National Aeronautic Association and The Ninety-Nines women pilots organization.

The 2005 Frank G. Brewer Trophy – awarded annually to an individual, group, or organization for significant contributions of enduring value to aerospace education in the United States – was presented to the Docent Corps of the National Air and Space Museum. The Docent Corps "has helped inspire generations of scientists, engineers, astronauts, and citizens," says the Museum's Director, General Jack Dailey. A particular mission of the all-volunteer group is to conduct tours and hands-on educational programs for visitors of all ages.